RESEARCH STUDIES
ON FIELD PRODUCTION
OF TOMATO TRANSPLANTS
IN SOUTHERN GEORGIA

Production Research Report No. 148

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
In Cooperation With
Georgia Coastal Plain Experiment Station
University of Georgia

RESEARCH STUDIES
ON FIELD PRODUCTION
OF TOMATO TRANSPLANTS
IN SOUTHERN GEORGIA

Production Research Report No. 148

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
In Cooperation With
Georgia Coastal Plain Experiment Station
University of Georgia

PREFACE

The production of tomato transplants is a very specialized form of agriculture. Transplant growers, like other agricultural producers, have been forced to look for ways to become more efficient. In 1961 the USDA initiated a research program involving scientists of several disciplines to find means of improving uniformity and quality of transplants and increasing yields. The results of this program have been made available in varied scientific publications, not all of which are available to growers and fieldmen for processors. This bulletin will serve as a single source of all significant research results on transplant production since 1961. It will form the basis for transplant production recommendations by extension specialists and representatives of processing companies. It will also be a useful reference for growers by presenting research results that are applicable now and will continue to be for the foreseeable future. Finally, it will be useful to future research workers by serving as a concise summary of research published in various scientific journals.

CONTRIBUTORS

C. A. Jaworski. research soil scientist, Southern Region, Agricultural Research Service; and Horticulture Department, Coastal Plain Station, University of Georgia, Tifton.

B. B. Brodie, research nematologist, Northeastern Region, Agricultural Research Service; and Plant Pathology Department, Cornell University, Ithaca, N.Y.; formerly at Tifton, Ga.

N. C. Glaze, research plant physiologist, Southern Region, Agricultural Research Service; and Horticulture Department, Coastal Plain Station, University of Georgia, Tifton.

S. M. McCarter, plant pathologist, Plant Pathology Division, University of Georgia, Athens; formerly Plant Science Research Division, Agricultural Research Service, Tifton, Ga.

J. M. Good, research nematologist, Northeastern Region, Agricultural Research Service, Beltsville, Md.

R. E. Webb, research plant pathologist, Northeastern Region, Agricultural Research Service, Beltsville, Md.

CONTENTS

RESEARCH STUDIES
ON FIELD PRODUCTION
OF TOMATO TRANSPLANTS
IN SOUTHERN GEORGIA

INTRODUCTION

Southern Georgia is the major source of tomato (*Lycopersicon esculentum* Mill.) transplants for Northern United States and Southern Canada. Over 700 million tomato transplants are grown each spring for shipment north (*2*).[1]

Most of these transplants are grown on recently cleared land to escape parasitic nematodes, weeds, and disease organisms (*4, 10*). Coastal Plain soils used for transplant production are infertile, acid, and low in organic matter (*21, 24, 50, 51, 52*). The seedbed is usually very rough because of a high content of trees and shrub debris. Under this "gypsy" system, the growers continually attempt to stay ahead of major nematode, weed, and disease problems (*10, 25*). Tomato transplants produced on such land lack size uniformity, which necessitates hand harvesting as transplants reach marketable size. Even if good plant size uniformity were possible on new land, the

mechanical harvesting would not be possible because of woody debris in the soil.

Extensive research in several disciplines of the Agricultural Research Service was initiated in 1960 to increase transplant yield and improve size uniformity under a permanent system of culture. With increased yields and improved size uniformity, mechanical harvesting could become a reality (*10*). Regardless of the type of culture, transplants must be free of nematodes, weeds, and diseases to meet certain minimum standards of Georgia Certification Regulations (*1*). Scientists in disciplines of soil science, nematology, plant physiology, and plant pathology have worked closely with State inspectors and industrial personnel to develop a feasible system for permanent transplant production. This report is a compilation of results of 8 years of research on field production of tomato transplants in the South.

CULTURAL PRACTICES

Precision Seeding

Precision seeding for improved size uniformity is one of many requirements for tomato-transplant mechanization (*10, 25*). Because raw tomato seed are small and irregular, they cannot be precision seeded at very high rates with currently used (1972) commercial seeders.

One concept of precision seeding—the Filcoat process—involves coating small, irregular seed to

a uniform shape and size and seeding with a special metering device. Commercially, this process gives the seeds a uniform clay coating that permits them to be precision seeded with Gramor seeders. Size uniformity of tomato seedlings was improved when this precision seeding concept was used in nutrition and clipping experiments (*10, 22, 23, 24, 25, 27,*); however, adequate moisture during germination was essential. The seeding rate was 18 seeds per foot of row, or about 1,050,000 seeds per acre. Plant beds were on 6-foot tractor spacings, with

---

[1] Italic numbers in parentheses refer to Literature Cited, p. 55.

four double rows on 14-inch centers and with double rows 2 inches apart. [2]

The newest concept of precision seeding is to enclose the seed in a water-soluble polymer tape (Rohtec seed tapes). The seeds are enclosed in the tapes in the laboratory, and a planter rolls these tape with the seed into the soil. Tape seeding was used under experimental and production conditions for one transplant growing season (1968), and the concept appears to have a bright future.

Tomato seed should be spaced from $2/5$ to $2/3$ inch apart, depending upon the row spacing, in order to have a high transplant yield. Most available precision seeders for raw seed are for precision seed spacing larger than that desirable for transplant production.

Seedbeds for precision seeding must be level and free of tree and shrub debris. Precision seeding is possible on land that has been cultivated for 2 or more years after clearing and that is relatively free of plant debris.

Fertilizer Placement

Initial tomato root growth consists of taproot elongation, with penetration about 1 inch deep by the time the cotyledons emerge. The growth after this relatively shallow penetration is as rapid laterally as vertically *(36)*. Because the tomato seed is small, the amount of phosphorus (P) available to the seedling from the seed is relatively small. The above facts indicate that most of the P should be placed in a band 1 to 1.5 inches directly below the seed. Most Coastal Plain soils used for transplant production are very low in available P. This low P content makes placement of fertilizer P directly below the seed important. Movement of P in the soil is slight compared with that of nitrogen (N) and potassium (K). This slight movement also contributes to the importance of optimum P placement.

Nutrition research indicates that high marketable yields and size uniformity can be obtained when the N-P-K is applied in a band 1 to 1.5 inches below the seed *(22, 24, 27, 50, 51, 52)*. In most nutrition experiments of this report,

[2] Seeding pattern was developed by W. S. Murphy, Campbell Soup Company, Cairo, Ga.

the N-P-K was applied in a 2.5- to 3-inch-wide band 1 to 1.5 inches below the seed.

Nutrition Rates

Murphy *(50, 51)* reported that nutrition rates influenced both yield and size uniformity of tomato transplants on recently cleared land. No marketable transplants were produced at the zero P rate, and responses to P were greater than those to K. He concluded that a minimum of 26 pounds of P and 50 pounds of K per acre, banded under the seed, are required to produce an early crop of tomato transplants. He also reported that both row and broadcast applications of P increased yield and size uniformity of tomato transplants. A high application of P banded in the row masked the effect of broadcast P.

Seven nutrition experiments on effects of N-P-K and dolomitic limestone (dolomite) on tomato transplant growth and yield were conducted under field conditions by the Plant Science Research Division from 1963 through 1965 *(22, 24)*. We used a complete factorial design with four replications.

Dolomite was broadcast and disked into the soil immediately before seeding. Other fertilizers, except for 20 pounds of N per acre side dressed in the 1964 experiments, were premixed and applied below the seed during seeding *(14)*.

In the 1963 experiment on Goldsboro loamy sand, variables were 20 and 40 pounds of N per acre; 17.5, 35, and 70 pounds of P per acre; and 25, 50, and 100 pounds of K per acre.

In two of the experiments in 1964, one on Goldsboro loamy sand and the other on Tifton loamy sand, variables were 40 and 60 pounds of N per acre; 35, 70, and 105 pounds of P per acre; 25 and 50 pounds of K per acre; and 0 and 2,000 pounds of dolomite per acre. In another experiment on Tifton loamy sand in 1964, variables were 0 and 2,000 pounds of dolomite per acre, with N source treatments.

In three experiments on Tifton loamy sand in 1965, the variables in the first were 20 and 60 pounds of N per acre; 10, 30, and 90 pounds of P per acre; 25 and 75 pounds of K per acre; and 2,000 pounds of dolomite per acre. The variables in the second experiment were the same as those in the first except both 0 and 2,000 pounds of

dolomite per acre were included. The variables in the third experiment were also the same as those in the first except broadcast P treatments of 0 and 35 pounds per acre were also included.

The fertilizer sources were superphosphate for P and muriate of potash for K. Urea supplied the N in 1963 and 1964; and a mixture of ammonium nitrate, urea, and ureaform each supplied 1/3 of the N in 1965. Ureaform was applied at 3.2 times the N rate required, based on N content, because only about 30 percent of its N becomes available during the average transplant growing season. The dolomite contained 57 percent calcium carbonate and 33 percent magnesium carbonate; 94 percent passed a U.S. No. 8 sieve and 52 percent passed a No. 60 sieve.

The soils used in these tests were highly acid and usually very infertile. Soil P and K were extracted with a 0.05 N hydrochloric and 0.025 N sulfuric acid solution. The Goldsboro loamy sand (pH 4.6) in the 1963 experiment had been cleared of pine trees and shrubs the preceding winter and was very low in available P (12 pounds per acre), available K (18 pounds per acre), calcium (Ca), and magnesium (Mg). The Goldsboro loamy sand (pH 5.0) in the 1964 experiment had produced commercial transplants in 1963 and was high in available P (149 pounds per acre) and medium in available K (69 pounds per acre). The Tifton loamy sand (pH 5.1) in the 1964 experiment had produced spring and fall vegetable transplants for 4 years and was very high in available P (596 pounds per acre) and low in available K (58 pounds per acre), Ca, and Mg. The Tifton loamy sand (pH 5.2) in the three experiments in 1965 had produced tomato transplants for 2 years and was very low in available P (10 pounds per acre), available K (14 pounds per acre), Ca, and Mg.

Campbell 146 tomato seed with 92-percent germination was grown in 1963, H-1350 with 96-percent germination in 1964, and H-1350 with 93-percent germination in 1965.

In 1963, seeding was on March 28, and transplants were harvested 44 days later. In 1964, the Goldsboro loamy sand experiment was seeded on March 12, and transplants were harvested 58 days later; the Tifton loamy sand experiments were seeded on April 16 and April 17, and transplants were harvested 45 and 48

days later, respectively. In 1965, the first experiment was seeded on March 12, and transplants were harvested from 42 to 48 days later. Transplants grown with the high levels of N-P were harvested 42 days after seeding, and those grown with the low levels of N-P 48 days after seeding. The second experiment in 1965 was seeded on March 11, and transplants were harvested from 41 to 48 days later, again depending on N-P levels. The third experiment in 1965 was seeded on April 3, and transplants were harvested 38 days later.

All transplants from a representative area of each plot, regardless of size, were harvested for yield and chemical analyses when the maximum number of transplants in that experiment or plot had attained marketable size. The transplants were classified into three sizes, with the large and medium sizes classified as marketable (table 1). Only marketable or marketable and cull data are presented. In commercial practice, fields are harvested repeatedly as transplants progressively reach marketable size. However, in these nutrition studies all transplants were harvested at one time to simulate machine harvesting.

In these nutrition experiments, transplants were not clipped because of limited research information on this cultural practice at that time. If transplants had been clipped, the yield would have been considerably higher and size uniformity would have been improved.

Shoot samples collected from representative transplants for elemental analyses were oven-dried at 70° C. for 48 hours, ground in a mill, and wet digested. P was determined colorimetrically by use of ammonium molybdate and stannous oxalate solutions. Cations were measured by atomic absorption spectrophotometry.

TABLE 1.—*Tomato transplant classification according to size*

Size classification	Stem diameter		Shoot height	
	Centimeter	Inch	Centimeter	Inch
Large	0.64 & >	0.25 & >	15.2-25.4	6-10
Medium	0.41-0.63	0.16-0.24	15.2-25.4	6.10
Culls	< 0.41	< 0.16	< 15.2	< 6

1 Sum of large and medium sizes are marketable transplants.
Source: (23).

The data were analyzed statistically, and Duncan's method was used for comparison of means *(13)*.

Nutrition Study Results

Experiment on Goldsboro loamy sand, 1963—Marketable tomato transplant yield increased from 280,000 plants per acre at the lowest N-P rate to 537,000 at the highest (table 2). The interaction between N and P was significant. The increase in marketable yield was related to improved size uniformity (a higher percentage of the total transplants at marketable size). Increasing the rate of K above 25 pounds per acre did not influence the yield or size uniformity.

Experiment on Goldsboro loamy sand, 1964—Marketable tomato transplant yield was reduced by windblown sand and a freeze at the time of seedling emergence. Marketable yield increased from 280,000 plants per acre at the lowest N-dolomite rate to 390,000 at the highest (table 3). The increase in marketable yield was related to improved size uniformity. High P rates did not increase marketable yield, probably because the soil was already high in available P (149 pounds per acre). As in the study on Goldsboro loamy sand in 1963, increasing the rate of K from 25 to 75 pounds per acre did not influence the yield or size uniformity.

Experiment on Tifton loamy sand, Test 1, 1964—Marketable tomato transplant yield did not increase significantly nor did size uniformity improve at high rates of N-P-K (table 4). High P rates did not increase marketable yield because the soil was already very high in available P (596 pounds per acre). Marketable yield increased from 296,000 plants per acre when 0 dolomite was applied to 490,000 when 2,000 pounds per acre was applied.

Many of the transplants, both marketable and culls, grown without dolomite exhibited severe Mg deficiencies, including characteristic chlorosis and the abscission of older leaves. These symptoms were much more severe on transplants on this Tifton loamy sand soil than on those on the Goldsboro loamy sand soil in 1964.

Experiment on Tifton loamy sand, Test 2, 1964—Marketable tomato transplant yield increased from 370,000 plants per acre when 0 dolomite was applied to 440,000 when 2,000 pounds per acre was applied (table 5). Mg deficiency symptoms were present on transplants grown without the dolomite but not on those with the dolomite.

Experiment on Tifton loamy sand, Test 1, 1965—Marketable tomato transplant yield increased from 350,000 plants per acre at the lowest N-P rate to 590,000 at the highest (table 6). Size uniformity also improved at the high N-P rates. Only 53 percent of the total transplants were marketable at the lowest N-P rate, whereas 78 percent were marketable at the highest. Transplants grown at the lowest N-P rate required about 6 more days to reach marketable size than transplants grown at the highest. Increasing the rate of K from 25 to 75 pounds per acre did not influence the yield or size uniformity.

Experiment on Tifton loamy sand, Test 2, 1965—Marketable tomato transplant yield and size uniformity increased as N-P-K rates increased (table 7). Only 54 percent of the total transplants were marketable at the lowest N-P-K rate, whereas 82 percent were marketable at the highest. Nutrient interactions were not significant. The application of 2,000 pounds of dolomite per acre did not increase the yield of transplants.

Experiment on Tifton loamy sand, Test 3, 1965—Marketable tomato transplant yield, which averaged 505,000 plants per acre for the experiment, did not increase at the highest N-P-K rates even though the percentage of marketable transplants increased as N-P-K rates increased (table 8). This experiment was carried out during a period of high soil temperatures. These high soil temperatures may have influenced the effect of nutrient rates, especially P.

Phosphorus and Magnesium Content

The P content in ovendried marketable tomato transplant shoots generally increased as the N-P rates increased. This increased P content in the transplant with increasing N-P application rates was significant in experiments with a large marketable yield response from the higher N-P rates (tables 9, 10, and 11). A very

TABLE 2.—*Effect of N-P-K rates of application on yield and percentage of marketable tomato transplants on newly cleared Goldsboro loamy sand, 1963* [1] [2]

N rate (pounds per acre)	Transplant yield per acre in soils with P rate of—			Mean yield per acre for N rates	Marketable transplants grown in soils with P rate of—			Mean marketable transplants for N rates
	17.5 pounds per acre	35.0 pounds per acre	70.0 pounds per acre		17.5 pounds per acre	35.0 pounds per acre	70.0 pounds per acre	
	Thousands				*Percent of total yield*			
20	280a	409ab	363a	351a	44a	58ab	53ab	52a
40	316a	439ab	537b	431b	49ab	67ab	72b	63b
Mean yield per acre for P rates.	293a	424b	450b	....	....	....	....	....
Mean marketable transplants for P rates.	....	....	....	....	47a	63b	63b	....

[1] K rates did not significantly affect yield; results are means for 3 K rates.
[2] Any 2 treatment means in the same block and followed by the same letter or letters are not significantly different at the 5-percent level.
Source: (24).

TABLE 3.—*Effect of N-P-K-dolomite rates of application on yield and percentage of marketable and cull tomato transplants on Goldsboro loamy sand, 1964*[1][2]

N-dolomite rates (pounds per acre)	Transplant yield per acre		Percentage of total yield	
	Marketable	Cull	Marketable	Cull
	Thousands	*Thousands*	*Percent*	*Percent*
40-0	280a	260a	53a	47 c
60-0	320 b	230a	59 b	41 bc
40-2,000 ...	360 bc	220a	63 bc	37ab
60-2,000 ...	390 c	170a	69 c	31a

[1] P-K rates did not significantly affect yield; results are means for 3 P rates and 2 K rates.

[2] Any 2 treatment means in the same column and followed by the same letter or letters are not significantly different at the 5-percent level.

Source: (22).

TABLE 4.—*Effect of N-P-K-dolomite rates of application on yield and percentage of marketable and cull tomato transplants on Tifton loamy sand, test 1, 1964*[1][2]

Dolomite rate (pounds per acre)	Transplant yield per acre		Percentage of total yield	
	Marketable	Cull	Marketable	Cull
	Thousands	*Thousands*	*Percent*	*Percent*
0	296a	390 b	43a	57 b
2,000	490 b	210a	71 b	29a

[1] N-P-K rates did not significantly affect yield; results are means for 2 N rates, 3 P rates, and 2 K rates.

[2] Any 2 treatment means in the same column and followed by the same letter are not significantly different at the 5-percent level.

Source: (22).

high P content in the transplant may be beneficial by enabling the plant to regenerate the new root system immediately after transplanting.

The Mg content of ovendried marketable transplant shoots ranged from 0.27 to 0.42 percent and increased as the dolomite rate to the soil increased and, in one case, decreased as the K rate increased (table 12). Transplants with slight Mg deficiency symptoms contained 0.39 percent or less Mg, and those transplants with severe Mg deficiency symptoms contained 0.30

TABLE 5.—*Effect of dolomite application on yield and percentage of marketable and cull tomato transplants in Tifton loamy sand, test 2, 1964*[1][2]

Dolomite rate (pounds per acre)	Transplant yield per acre		Percentage of total yield	
	Marketable	Cull	Marketable	Cull
	Thousands	*Thousands*	*Percent*	*Percent*
0	370a	210 b	64a	36 b
2,000	440 b	140a	76 b	24a

[1] Results are means of 11 N sources.

[2] Any 2 treatment means in the same column and followed by the same letter are not significantly different at the 5-percent level.

Source: (22).

percent or less Mg. The severity of Mg deficiency without dolomite indicates that the greatest benefit from dolomite was in supplying Mg.

Nutrition Rates Summary

These nutrition studies generally showed that a N rate of at least 40 to 60 pounds per acre is necessary to produce a high marketable tomato transplant yield or a good size uniformity, or both. P is the major nutrient that limits high transplants yield. Four experiments showed that high P rates below the seed row are necessary for high marketable yield or good size uniformity, or both. The soils in four of these experiments contained less than 15 pounds of available P per acre. Two experiments in these nutrition studies showed that marketable yield was not affected by increasing P rates because the available soil P was already more than 100 pounds per acre. High K rates of application are not usually necessary for high marketable transplant yield, and a K rate of 25 pounds per acre appears adequate for optimum transplant yield. Three experiments showed that the application of dolomite increased marketable transplant yield and improved size uniformity, probably by lowering soil acidity and increasing the Mg supply.

Nitrogen Sources and Rates

Murphy (52) emphasized that emerging tomato seedling need an adequate supply of N until they are 4 to 5 inches tall. Then the growth

TABLE 6.—*Effect of N-P-K rates of application on yield and percentage of marketable tomato trans-plants on Tifton loamy sand, test 1, 1965* [1] [2]

| N rate (pounds per acre) | Transplant yield per acre on soils with P rate of— | | | Mean yield per acre for N rates |
	10 pounds per acre	30 pounds per acre	90 pounds per acre	
	.... *Thousands*			
20	350	400	420	390a
40	430	570	590	530 b
Mean yield per acre for P rates.	390a	485 b	505 b	....
	.... *Percent of total yield*			
20	53a	59a	57a	57a
40	61a	74 b	78 b	71 b
Mean marketable transplants for P rates.	57a	66 b	68 b	....

[1] K rates did not significantly affect yield; results are means for 2 K rates.

[2] Any 2 treatment means in the same block and followed by the same letter are not significantly different at the 5-percent level.

Source: (24).

rate should be slowed by reducing the N supply to harden the plants. Use of nitrogen sources with various release patterns would, therefore, be benefical for tomato transplant growth. For-mulations containing both rapid and slow release patterns were suggested. In Murphy's tests a mixture of ammonium, nitrate, urea, and ureaform N at 7.5, 7.5, 5, and 10 pounds per acre, respectively, when banded under the seed, produced high yields of good-quality tomato transplants on a Norfolk loamy sand.

Five field experiments on the effects of N sources and rates on tomato transplant yield and size uniformity were conducted at Tifton from 1964 through 1966 on Tifton and Goldsboro loamy sand (27). Each experiment consisted of 11 or 12 N sources at two N rates except for the experiment on Tifton loamy sand in 1964 (table 13), which consisted of 11 N sources at one N rate but with 0 and 2,000 pounds per acre of broadcast dolomite. Treatments in each ex-periment were replicated four times in ran-domized block designs.

In 1965 and 1966, except for Mixtures 1 and 3 in 1966, ureaform was applied at 3.2 times the N rate required, based on N content, because only about 30 percent of its N becomes available during the average tomato transplant growing season.

In all experiments P was supplied by superphosphate, except for the P supplied by the diammonium phosphate and ammonium polyphosphate N sources. K was supplied by muriate of potash. The N-P-K were premixed and applied with a device that percisely placed and metered the nutrient during seeding (14). Dolomite was broadcast and disked into the soil before seeding.

Some of the N sources involved either 2-chloro-6(trichloromethyl) pyridine (N-Serve) or ammonium polyphosphate. N-Serve is highly toxic to *Nitrosomonas* organisms that oxidize ammonium N to nitrite N and might be expected to reduce the loss of N through leaching of nitrates after ammonium N is oxidized. Am-monium polyphosphate, which contains 21

percent N and 26.4 percent P, is an experimental fertilizer formulated by the Tennessee Valley Authority.

Three N mixtures were evaluated. Mixture 1 consisted of ammonium nitrate, urea, and ureaform, each supplying ⅓ of the actual N. Mixture 2 was the same as Mixture 1 except ureaform was applied at 3.2 times the N rate. Mixture 3 consisted of ammonium nitrate supplying ½ of the actural N, urea supplying ⅙, and ureaform ⅓.

Seed of tomato cultivar C-146 with 92-percent germination were seeded in 1964, seed of H-1350 with 93-percent germination in 1965, and seed of H-1350 with 99-percent germination in 1966. The seed were Filcoat processed and precision seeded as in the nutrition studies. nutrition studies.

In 1964 the experimental plots of Goldsboro loamy sand were seeded on March 14, and about 50 percent of the potential seedlings had emerged by March 28. Windblown sand on March 30 and 31 killed about 10 percent of the

TABLE 7.—*Effect of N-P-K-dolomite rates of application on yield and percentage of marketable tomato transplants on Tifton loamy sand, test 2, 1965* [1] [2]

N-K rates (pounds per acre)	Transplant yield per acre on soils with P rate of—			Mean yield per acre for K rate of—		Mean yield per acre for N rates
	10 pounds per acre	30 pounds per acre	90 pounds per acre	25 pounds per acre	75 pounds per acre	
			Thousands			
20-25	371	427	471	423	....	445a
20-75	448	456	497	....	467	
60-25	465	549	582	532	....	555 b
60-75	545	573	615	....	578	
Mean yield per acre for P rates.	457a	501 b	541 c	....	....	....
Mean yield per acre for K rates.	....	....	....	477a	523 b	....
			Percent of total yield			
20-25	54	59	66	60	....	61a
20-75	59	60	67	....	62	
60-25	67	72	74	71	....	74 b
60-75	75	73	82	....	77	
Mean marketable transplants for P rates.	64a	66a	72 b	....	....	....
Mean marketable transplants for K rates.	....	....	....	65a	69 b	....

[1] Dolomite rates did not significantly affect yield; results are means for 2 dolomite rates.

[2] Any 2 treatment means in the same block and followed by the same letter are not significantly different at the 5-percent level. Nutrient interactions were not significant.

Source: (24).

plants, and a freeze on March 31 destroyed about 10 to 20 percent more. Another light freeze on April 10 injured many plants but did not affect stands. Transplants grown with cottonseed meal as the N source were harvested and graded for size after 51 days, and those grown with all other formulations as the N source after 60 days. The rainfall from seeding to harvest was 10.6 inches and was supplemented with several unrecorded irrigations as needed.

In 1964 the experimental plots on Tifton loamy sand were seeded on April 17. Transplants grown with cottonseed meal, diammonium phosphate, and ammonium sulfate (without N-Serve) as the N source were harvested and graded for size after 42 days and all

TABLE 8.—*Effect of N-P-K rates of application on percentage of marketable tomato transplants on Tifton loamy sand, test 3, 1965* [1]

| N-K rates (pounds per acre) | Marketable transplants grown in soils with P rates of [2] [3] — | | | | | |
	10-0	10-35	30-0	30-35	90-0	90-35
	Percent					
20-25	55.3a	68.0 bc	65.8 bc	71.0 bc	68.8 bc	69.8 bc
20-75	65.8 bc	69.5 bc	64.8 bc	65.3 b	67.0 bc	71.0 bc
60-25	64.3 b	68.0 bc	74.5 bc	73.8 bc	66.8 bc	67.3 bc
60-75	71.8 bc	76.5 c	74.5 bc	74.0 bc	71.5 bc	71.8 bc

[1] Any 2 treatment means followed by the same letter or letters are not significantly different at the 5-percent level.

[2] The first number is pounds of P per acre in the row, and the second is pounds of P per acre broadcast.

[3] Mean yields per acre are as follows:
Mean for 2 rates of N:
20 pounds of N per acre - 66.8a percent
60 pounds of N per acre - 71.2 b percent
Mean for 2 rates of K:
25 pounds of K per acre - 67.7a percent
75 pounds of K per acre - 70.3 b percent
Mean for 2 rates of P (broadcast):
0 pounds of P per acre - 67.5a percent
35 pounds of P per acre - 70.5 b percent

TABLE 9.—*Effect of N-P-K rates of application on P content (percentage) of ovendried marketable tomato transplant shoots on Goldsboro loamy sand, 1963* [1] [2]

| N rate (pounds per acre) | P content of shoots with P rate of— | | | Mean P content of shoots for N rates |
	17.5 pounds per acre	35 pounds per acre	70 pounds per acre	
	.... *Percent*			
20	0.22a	0.28ab	0.38 c	0.29a...
40	.27a	.33 bc	.37 c	.32 b..
Mean for 3 P rates.	.24a	.31 b	.37 c	....

[1] K rates did not significantly affect P content; results are means for 2 K rates.

[2] No 2 treatment means in the same block and followed by the same letter or letters differ at the 5-percent level.

other transplants after 45 days. The rainfall from seeding to harvest was 4.4 inches and was supplemented with 4.9 inches to harvest was 4.4 inches and was supplemented with 4.9 inches of water in 11 irrigations as needed.

In 1965 plots in the first experiment on Tifton loamy sand were seeded on March 17, and the weather subsequently favored the development of good stands. Transplants grown with sodium nitrate as the N source were harvested and graded for size 47 days after seeding; those grown with higher levels of ammonium polyphosphate and the lower levels of other formulations as the N source were harvested and graded 41 days after seeding; and those grown with other formulations only 38 days after

TABLE 10.—*Effect of N-P-K rates of application on P content (percentage) of ovendried marketable tomato transplant shoots on Tifton loamy sand, test 1, 1965* [1] [2]

N rate (pounds per acre)	P content of shoots with P rate of—			Mean P content of shoots for N rates
	10 pounds per acre	30 pounds per acre	90 pounds per acre	
	.... Percent			
20	0.23a	0.31 b	0.37 c	0.30a
60	.22a	.39 c	.41 c	.34 b
Mean for 3 P rates	.23a	.35 b	.39 b	....

[1] K rates did not significantly affect P content; results are means for 3 K rates.
[2] Any 2 treatment means in the same block and followed by the same letter or letters are not significantly different at the 5-percent level.

TABLE 11.—*Effect of N-P-K-dolomite rates of application on P content of oven dried marketable tomato transplant shoots on Tifton loamy sand, test 2, 1965* [1] [2]

N-dolomite rates (pounds per acre)	P content of shoots with P rate of—			Mean P content of shoots for N rates
	10 pounds per acre	30 pounds per acre	60 pounds per acre	
	.... Percent			
20-0	0.22ab	0.29 c	0.39 e	0.31a
20-2,000	.21ab	.30 c	.40 e	
60-0	.20a	.36 d	.41 e	.34 b
60-2,000	.25 b	.35 d	.45 f	
Mean for 3 P rates	.23a	.32 b	.41 c	....

[1] K rates did not affect P content; results are means for 2 K rates.
[2] Any 2 treatment means in the same block and followed by the same letter or letters are not significantly different at the 5-percent level.

TABLE 12.—*Effect of N-P-K-dolomite rates of application on Mg content of ovendried marketable tomato transplant shoots on two soil types, 1964* [1]

Soil type and dolomite rate (pounds per acre)	Mg content of shoots with K rate of—		Mean Mg content of shoots for dolomite rates
	25 pounds per acre	50 pounds per acre	
	Percent		
Goldsboro loamy sand: [2]			
0	0.36 b	0.33a	0.35a
2,000	.42 d	.39 b	.41 b
Mean for 2 K rates.	.39 b	.36a	....
Tifton loamy sand, test 1: [3]			
0	.27a	....	....
2,000	.39 b	....	....
Tifton loamy sand, test 2: [4]			
0	.29a	....	....
2,000	.35 b	....	....

[1] Any 2 treatment means in the same block and followed by the same letter are not significantly different at the 5-percent level.

[2] N-P rates did not significantly affect Mg content; results are means for 2 N rates and 3 P rates.

[3] N-P-K rates did not significantly affect Mg content; results are means for 2 N rates, 3 P rates, and 2 K rates.

[4] Results are means for 11 N sources and 4 replications.

seeding. The rainfall from seeding to harvest was 7.33 inches and was supplemented with 1.45 inches of water in six irrigations as needed.

In 1965 plots in the second experiment on Tifton loamy sand were seeded on April 2, and transplants from all plots were harvested and graded for size after 39 days. The rainfall from seeding to harvest was only 3.6 inches but was supplemented with 2.5 inches of water in seven irrigations as needed.

In 1966 the experimental plots were seeded on March 22 and cold, dry climatic conditions delayed germination. About 90 percent of the seedlings had emerged by April 11. Nonclipped transplants were harvested and graded for size from a representative area of each plot after 42 to 52 days, when the maximum number of transplants in that plot had attained marketable size. The rainfall from seeding to the first harvest

was only 1.55 inches but was supplemented with 4.95 inches of water in 16 irrigations as needed.

In all N experiments except one, yield data were collected from nonclipped transplants. In 1966 the data were collected on both nonclipped and moderately clipped plants. Transplants were clipped after yield data for nonclipped transplants were collected. Uneven growth rates due to different N sources and rates made clipping on different dates necessary. When yield data from nonclipped transplants were collected 42 days after seeding, the transplants were clipped 42 and 49 days after seeding. When yield data for nonclipped transplants were collected 45 days after seeding, the transplants were clipped 47 and 49 days after seeding . When yield data from nonclipped transplants were collected 49 and 52 days after seeding, the transplants were clipped on the same day of harvest. Fifty-two days after

TABLE 13.—*Nitrogen sources and rates used on 5 field experiments for production of tomato transplants, 1964-66* [1]

N source [2]	N content	1964				1965				1966			
		Goldsboro loamy sand, [3] rate of application for N per acre		Tifton loamy sand, [4] N rate—40 pounds per acre, rate of application for dolomite per acre		Tifton loamy sand, test 1, [5] rate of application for N per acre		Tifton loamy sand, test 2 [5] rate of application for N per acre		Goldsboro loamy sand, [6] nonclipped transplants, rate of application for N per acre		Goldsboro loamy sand, [6] clipped transplants, [7] rate of application for N per acre	
		20 pounds	40 pounds	0 pounds	2,000 pounds	20 pounds	60 pounds	20 pounds	60 pounds	20 pounds	60 pounds	40 pounds	80 pounds
	Percent												
Urea	45	*	*	*	*	*	*	*	*	*	*	*	*
Ureaform [8]	33	*	*	*	*	*	*	*	*	*	*	*	*
Cottonseed meal	6	*	*	*	*	*	*	*	*				
Ammonium nitrate	33	*	*	*	*	*	*	*	*	*	*	*	*
Ammonium sulfate	20.5	*	*	*	*	*	*	*	*	*	*	*	*
Ammonium-nitrate-limestone (ANL)	20.5	*	*	*	*	*	*	*	*	*	*	*	*
Ammonium polyphosphate	21	...				*	*			*	*	*	*
Ammonium sulfate (with 2% N-Serve)	20.5	*	*	*	*	*	*	*	*	*	*	*	*
Ammonium sulfate (with 1% N-Serve)	20.5	*	*	*		*	*	*	*				
Ammonium sulfate (with 0.5% N-Serve)	20.5	*	*	*		*	*	*	*				
Sodium nitrate	16.5	*	*	*	*	*	*	*	*	*	*	*	*
Diammonium phosphate	18	*	*	*	*	*	*	*	*	*	*	*	*
Mixture 1: ⅓ ammonium nitrate, ⅓ urea, ⅓ ureaform		*	*	*						*	*	*	*
Mixture 2: ⅓ ammonium nitrate, ⅓ urea, ⅓ ureaform										*	*	*	*
Mixture 3: ½ ammonium nitrate, ⅙ urea, ⅓ ureaform										*	*	*	*

seeding, most of the transplants were beginning to exhibit N deficiency symptoms, so 20 pounds of N per acre from ammonium nitrate was broadcast over all the plots in the entire experiment. Thirteen days later, yield data from clipped transplants were collected in all plots.

Nitrogen Study Results

Experiment on Goldsboro loamy sand, 1964—Tomato transplants in all plots except those transplants grown with cottonseed meal and those with diammonium phosphate at 40 pounds of N per acre as the N source exhibited N deficiency symptoms 44 days after seeding. High rates of cottonseed meal and of diammonium phosphate produced the most attractive transplants and, together with ammonium sulfate, produced the most marketable transplants (table 14). The marketable yield was lowest and size uniformity was poorest in plots with sodium nitrate and those with Mixture 1 as the N source (tables 14 and 15). The low marketable yield from the N mixture was probably because less than one-third of the N in the ureaform was nitrified within the short plant-growing season and because much of the nitrate from the ammonium nitrate was leached away by excessive rainfall.

Experiment on Tifton loamy sand. 1964—Plant stands were highest in plots with diammonium phosphate and those with Mixture 1 as N sources, and lowest in plots with cottonseed meal and with sodium nitrate as the N source. The marketable transplant yield was highest (560,000 per acre) with diammonium phosphate plus dolomite as the N source (table 14). Most transplants grown without dolomite exhibited severe Mg deficiency symptoms. Exceptions were those transplants grown with ammonium-nitrate-limestone (ANL), which contained 4.2 percent Mg and 7.5 percent Ca. Marketable yield was lowest and size uniformity was poorest in plots with sodium nitrate as the N source, probably because of losses of N by leaching.

Experiment on Tifton loamy sand. Test 1, 1965—Tomato transplants grown with sodium nitrate as the N source exhibited extreme N deficiency symptoms. Those grown with the high rate of ammonium polyphosphate (and also, to a much less degree, those grown with the high rate

[1] Asterisks indicate the treatments used in each individual experiment.

[2] Total amounts of N supplied by the three sources are shown for the mixtures. Mixture 1 and Mixture 3 were not corrected for the rate of N release from ureaform. In Mixture 2, ureaform was supplied at 3.2 times the N rate required because only about 30 percent of its N becomes available during the average transplant growing season.

[3] P applied at rate of 105 pounds per acre, K at 25, and dolomite at 2,000.

[4] P applied at rate of 105 pounds per acre and K at 25.

[5] P applied at rate of 70 pounds per acre, K at 25, and dolomite at 2,000.

[6] P applied at rate of 70 pounds per acre and K at 25.

[7] These transplants were clipped after nonclipped yield data were collected. All plots received 20 pounds broadcast N per acre from ammonium nitrate 52 days after seeding.

[8] Corrected for its rate of N release in 1965 and 1966.

Source: (27).

TABLE 14.—Effect of N sources and rates on yield of marketable tomato transplants [1]

N source	N rate	1964 Goldsboro loamy sand [2]	1964 Tifton loamy sand, Dolomite rate of application		1965 Tifton loamy sand, Test 1	1966 Goldsboro loamy sand	
			0 pounds per acre	2,000 pounds per acre		Nonclipped [3]	Clipped [4]
			Thousands				
Urea	Low	360 bcd	. . . .	. . . .	490 b	700 cd	820
	High		390 bcde	470 f	620 cdef		
Ureaform	Low	330abc	. . . .	. . . .	480 b	695 bcd	802
	High		290a	460 ef	650 def		
Cottonseed meal	Low	430 d	. . . .	. . . .	570 bcde	. . . .	. . . .
	High		410 def	430 ef	630 cdef		
Ammonium nitrate	Low	330abc	. . . .	. . . .	480 b	650abc	759
	High		320a	440 ef	580 bcde		
Ammonium sulfate	Low	370cd	. . . .	. . . .	640 def	625ab	791
	High		430 ef	430 ef	620 cdef		
Ammonium-nitrate-limestone (ANL)	Low	330abc	. . . .	. . . .	. . . .	610a	803
	High		340abc	400 cdef	. . . . .		
Ammonium polyphosphate	Low	. . . .	. . . .	. . . .	650 def	. . . .	. . . .
	High				480 b		
Ammonium sulfate (with 2% N-Serve)	Low	. . . .	. . . .	. . . .	. . . .	670abcd	778
	High						
Ammonium sulfate (with 1% N-Serve)	Low	350 bcd	. . . .	. . . .	510 bc	645abc	807
	High		350abcd	440 ef	680 ef		
Ammonium sulfate (with 0.5% N-Serve)	Low	360 bcd	. . . .	. . . .	510 cdef	. . . .	. . . .
	High		470 f	450 ef	630 cdef		
Sodium nitrate	Low	280ab	. . . .	. . . .	80a	675abcd	770
	High		290a	330ab	130a		
Diammonium phosphate	Low	380 cd	. . . .	. . . .	540 bcd	685 bcd	773
	High		410 def	560 g	550 bcd		
Mixture 1	Low	250a	. . . .	. . . .	. . . .	725 d	821
	High		340abc	470 f	. . . .		
Mixture 2	Low	. . . .	. . . .	. . . .	560 bcd	665abcd	819
	High		. . . .	. . . .	700		
Mixture 3	Low	. . . .	. . . .	. . . .	. . . .	700 d	848
	High		. . . .	. . . .	. . . .		

See footnotes at end of table.

TABLE 14.—Effect of N sources and rates on yield of marketable tomato transplants [1] —Continued

N source	N rate	Yield per acre: Year, soil type, treatment					
		1964 Goldsboro loamy sand [2]	1964 Tifton loamy sand, Dolomite rate of application		1965 Tifton loamy sand, Test 1	1966 Goldsboro loamy sand	
			0 pounds per acre	2,000 pounds per acre		Nonclipped [3]	Clipped [4]
		Thousands					
N mean	Low				510a	640a	784
	High				570 b	702 b	814

[1] Any 2 treatment means in the same column or block and followed by the same letter or letters are not significantly different at the 5-percent level.
[2] Yields are the means of 2 N rates; no significant difference between N rates. *
[3] Yields are the means of 2 N rates; interaction of N source x rate was not significant.
[4] No 2 treatment means differ at the 5-percent level.
Source: *(27)*.

of diammonium phosphate) exhibited chlorotic leaves and retarded growth.

Marketable transplant yield was highest (700,000, or 83 percent of the total transplants) in plots with the high rate of Mixture 2 as the N source (tables 14 and 15). Marketable transplant yield was lowest (80,000, or 13 percent of the total transplants) in plots with the low rate of sodium nitrate as the N source. Marketable transplant yields were not significantly different in plots with high rates of urea, ureaform, cottonseed meal, ammonium sulfate with or without N-Serve, ammonium polyphosphate, and Mixture 2 as the N source. The mean marketable yield from these seven treatments ranged from 620,000 to 700,000 transplants per acre; total stands ranged from 670,000 to 850,000 plants per acre. Marketable yield was positively correlated with size uniformity.

Experiment on Tifton loamy sand, Test 2, 1965—The N source had no effect on size uniformity of tomato transplants harvested. Significantly larger numbers of medium, marketable, and total transplants were produced at the low N rate than at the high (table 16). This superiority of the low N rate was probably due to the lower resultant concentration of soluble salts in the soil during the relatively dry season. Total rainfall from seeding to harvest was unusually light, and leaching of nutrients

was probably slight, which may well explain the similarity of yields between N sources. The N rate had no effect on the percentage of marketable transplants.

Experiment on Goldsboro loamy sand, 1966—Both the N source and the rate of fertilization affected the marketable yield from nonclipped tomato transplants, whereas only the N source affected the percentage of marketable transplants (tables 14 and 15). The marketable yield was largest (725,000 transplants per acre, or 82 percent of the total transplants) in plots with Mixture 1, containing ureaform not corrected for its rate of N release. The marketable yield was lowest (610,000 transplants per acre, or 68 percent of the total transplants) in plots with ANL. Increasing the N level from 20 to 60 pounds per acre increased the marketable yield by an average of 62,000 transplants per acre from all N sources.

Neither the N source nor the rate of fertilization affected the marketable yield (average of 799,000 transplants per acre) after clipping and the application of an additional 20 pounds of N per acre (table 14). However, the N source affected the percentage of marketable transplants, the lowest percentages being produced in plots with ammonium sulfate and ammonium nitrate as sources of N. The mean percentage of marketable transplants for all N sources in-

TABLE 15.—*Effect of N sources and rates on percentage of marketable tomato transplants* [1]

N source	N rate	Percentage of total yield: Year, soil type, treatment					
		1964 Goldsboro loamy sand	1964 [2] Tifton loamy sand, Dolomite rate of application		1965 Tifton loamy sand, Test 1	1966 [3] Goldsboro loamy sand	
			0 pounds per acre	2,000 pounds per acre		Nonclipped	Clipped
				Percent			
Urea	Low	57 def	....	....	64 bcd	78 bc	91 bc
	High	61 ef	62	75	79 ef		
Ureaform	Low	49 bcd	....	....	65 bcde	76abc	92 c
	High	53 cdef	50	79	82 f		
Cottonseed meal	Low	64 f	....	....	76 cdef	....	....
	High	61 ef	79	83	81 f		
Ammonium nitrate	Low	55 def	......	......	56 b	78 bc	86ab
	High	48 bcd	57	70	75 cdef		
Ammonium sulfate	Low	53 cdef	....	....	76 cdef	72ab	85a
	High	64 f	75	75	76 cdef		
Ammonium-nitrate-limestone (ANL)	Low	54 cdef	....	....	....	68a	88abc
	High	49 bcd	63	74	....		
Ammonium polyphosphate	Low	....	....	....	80 f	....	....
	High	....	....	....	65 bcde		
Ammonium sulfate (with 2% N-Serve)	Low	....	....	....	....	75abc	91 bc
	High	....			....		
Ammonium sulfate (with 1% N-Serve)	Low	53 cdef	....	....	69 bcdef	73ab	89abc
	High	55 def	63	79	81 f		
Ammonium sulfate (with 0.5% N-Serve)	Low	53 cdef	....	....	77 def	....	....
	High	59 def	77	74	80 f		
Sodium nitrate	Low	51 bcde	....	....	13a	74abc	91 bc
	High	40ab	58	66	18a		
Diammonium phosphate	Low	62 ef	....	....	65 bcde	75abc	91 bc
	High	54 cdef	62	85	74 cdef		
Mixture 1	Low	37a	....	....	....	82 c	91 bc
	High	43abc	53	73	....		
Mixture 2	Low	....	....	....	71 cdef	76abc	90abc
	High				92 f		
Mixture 3	Low	....	....	....	....	78 bc	91 bc
	High						

See footnotes at end of table.

TABLE . 15.—*Effect of N sources and rates on percentage of marketable tomato transplants* [1]
—Continued

N source	N rate	Percentage of total yield: Year, soil type, treatment					
		1964 Goldsboro loamy sand	1964 [2] Tifton loamy sand, Dolomite rate of application		1965 Tifton loamy sand, Test 1	1966 [3] Goldsboro loamy sand	
			0 pounds per acre	2,000 pounds per acre		Nonclipped	Clipped
		Percent					
N mean	Low	53a	....		65a	72a	88a
	High	53a	64a	76 b	73 b	78 b	90a

[1] Any 2 treatment means in the same column or block and followed by the same letter or letters are not significantly different at the 5-percent level.

[2] No significant difference between N sources or interaction of N source x lime.

[3] Percentages are the means of 2 N rates; N rates and interactions of N source x rates were not significant.

Source: (27).

creased from 75 for the nonclipped transplants to 89 for the clipped (table 15).

Nitrogen Sources and Rates Summary

Sodium nitrate and ammonium nitrate are generally the least effective N sources when all the fertilizer is applied at seeding. However, under conditions of low rainfall where leaching is slight, sodium nitrate and ammonium nitrate are as effective as other N sources. Rainfall during the season for growing tomato transplants is generally heavy enough to make the loss of N by leaching a major problem.

Because ANL contains Ca and Mg, it could be more effective than any other N source by supplying these elements and by raising the pH of highly acid, Mg-deficient soils. Mg deficiency and excessive acidity, however, probably can be corrected more efficiently by the addition of dolomite (22).

Initially, we thought that the use of N-Serve would delay nitrification and thus increase the marketable transplant yield by reducing the loss of N by leaching. However, in these studies,

TABLE 16.—*Effect of N sources and rates on yield and percentage of tomato transplants. Tifton loamy sand, Test 2, 1965* [1] [2]

Class of transplants	Yield per acre at N rate of—	
	20 pounds per acre	60 pounds per acre
	Thousands	
Large	51a	75 b
Medium	530 b	460a
Total marketable	581 b	535a
Culls	230a	220a
Total marketable and ..... culls	811 b	755a
	Percent of total yield	
Total marketable	72a	71a
Culls	28a	29a

[1] Results are means of 12 N sources; no significant difference between sources.

[2] Any 2 treatment means in the same row and followed by the same letter are not significantly different at the 5-percent level.

Source: (27).

mixing N-Serve with ammonium sulfate did not increase the marketable transplant yield above that from ammonium sulfate alone.

Ammonium polyphosphate, especially at the high rate, was toxic to the tomato seedlings. Leaves yellowed, even at the low rate, although the marketable yield was high.

Cottonseed meal produced not only very attractive marketable transplants but also the greatest number of marketable transplants. However, this material appears to be too expensive to use as the sole N source for growing transplants.

The most promising N sources for producing tomato transplants, when applied entirely at seeding, were urea, ureaform, ammonium sulfate, diammonium phosphate, and the mixtures of ammonium nitrate, urea, and ureaform. Diammonium phosphate has the disadvantage of being toxic to the seedlings when placed too close to the seed or applied at a high rate. Even though a number of N sources were comparable in marketable yield, the mixture of three N sources is suggested for transplant production by virtue of variable N availabililty of its components (27, 52).

In general, yield of marketable transplants was highest and size was more uniform in plots with N rates of 40 or 60 pounds per acre than with rates of 20 pounds (27). Even higher rates of N may be necessary if clipping is used as a cultural practice for field holding marketable-size transplants. In relatively dry growing seasons, however, the high N levels might reduce marketable yields by imparing plant stands.

Predicting Seeding Dates

Methods of biometeorological measurements to predict tomato seeding dates for projected transplant harvest dates would help in timing production with needs of growers in the North (28). One method of using temperature to predict transplant growth is the degree-day method. Preliminary results indicate that an accumulation of 777 degree days (with a threshold value of 50° F.) from seeding to first harvest were necessary to produce a marketable nonclipped transplant (60).

Another prediction method called effective heat units (EHU) involves a maximum (85° F.) as well as a minimum temperature (50° F.)

(28). The EHU method does not appear to be an improvement over the degree-day method, and the ease of computation favors the degree-day method (60).

The major weakness of a heat unit method is that climatic conditions in either the transplant-growing or fruit-production areas often deviate considerably from the normal means. For example, transplanting was delayed over 2 weeks because of unfavorable weather conditions in much of the Midwest in 1966, while at the same time conditions in south Georgia were generally favorable for rapid transplant growth.

Transplant Storage

Tomato transplant storage as a technique for holding marketable size transplants during unfavorable transplanting conditions and for insuring rapid transplant availability when transplanting conditions are favorable was evaluated in five field experiments during 1964 and 1965 (29, 31, 33). These experiments were conducted at Bowling Green, Ohio; Swedesboro, N.J.; Leipsic, Ohio; and two at Beltsville, Md. (tables 17 to 21). Cultivar II-1350 was used in all experiments and transplants were field grown near Tifton, Ga. After harvest, the roots were rolled in moist peat moss and bundles of 50 transplants were wrapped in paper and packed in keystone-shaped crates in accorance with commerical practices (46).

For each experiment at Bowling Green, Leipsic, and Swedesboro, transplants for all treatmemts were harvested on the same date and stored at these northern locations. However, for the 1965 experiment at Beltsville, transplants for all treatments were harvested on the same date and were stored in Tifton. Because environmental differences of the various transplanting dates after storage could possible affect the results, for the 1966 experiment at Beltsville, transplants for the various storage periods were harvested on different dates and stored in Tifton to permit planting of stored and nonstored transplants on the same date.

In two of the experiments, treatments in addition to storage treatments were included. Moderately clipped transplants without storage were included at Leipsic (table 19). Transplants grown at four different N-P rates were evaluated

in the 1965 storage experiment at Beltsville (table 20).

Except for transplants produced with different N-P levels for the 1965 Beltsville experiment, transplants were produced with recommended nutrition levels. Transplants were not clipped except those moderately clipped in the ᵗ ᵢc experiment.

The temperatures for transplant storage were 50° to 60° F. at Bowling Green, 50° to 55° at Swedesboro, and 50° at Leipsic and Beltsville.

Cultivation, irrigation, fertilization, and spraying plants after transplanting were similar to the commercial field practices in each area. Plant survival and multiple fruit harvest data were collected for each experiment.

A randomized block design with four replications was used. Data were analyzed statistically and Duncan's method was used for camparison of means (13).

Transplant Storage Study Results

Experiment at Bowling Green, Ohio, 1964— Tomato transplants that were not stored were of good quality, showed no disease lesions, survived 100 percent, and yielded 38.4 tons of marketable fruit per acre (table 17). Transplants stored for 5 days were of good quality, showed only slight damage to the lower leaves, survived 100 percent, and yielded 39.9 tons of marketable fruit per acre. Transplants stored for 10 days were of fair to poor quality and showed scattered lesions of soft rot, but they survived 100 percent and yielded 29.7 tons of marketable fruit per acre.

Experiment at Swedesboro, N.J., 1964— Tomato transplants stored for 6 days were of good quality, showed about one-third of the leaves yellow, survived 95 percent, and yielded 27.8 tons of marketable fruit per acre (table 18). Approximately 2.5 tons of marketable fruit were left on the plants after the last harvest. Plant survival and fruit yield of the stored transplants were not significantly lower than that of the nonstored, but the first harvest of the stored transplants was about 6 days later than that of nonstored.

Transplants stored for 12 days were of only fair quality and showed considerable yellowing of leaves and excessive new root proliferation. This last feature made separating the transplants

TABLE 17.—*Effect of tomato transplant storage duration on plant survival and marketable fruit yield, Bowling Green, Ohio, 1964* [1]

Days in storage [2]	Plant survival	Fruit yield per acre [3]	
	Percent	Thousands	Tons
0	100	346 b	38.4 b
5	100	357 b	39.9 b
10	100	261 a	29.7 a

[1] Any 2 treatment means in the same column and followed by the same letter are not significantly different at the 5-percent level.

[2] Does not include 2 days in transit.

[3] Marketable fruit includes anthracnose-infected fruit but not rotten fruit.

Source: (33).

TABLE 18.—*Effect of tomato transplant storage duration on plant survival, fruit grade, and marketable fruit yield, Swedesboro, N.J., 1964* [1]

Days in storage [2]	Plant survival	Fruit yield per acre		
		Marketable	Culls	Total
	Percent	Tons		
0	100 b	31.4 b	1.2 b	32.6 b
6	95 b	27.8 b	1.1 b	28.9 b
12	77 a	20.0 a	0.4 a	20.4 a

[1] Any 2 treatment means in the same column and followed by the same letter are not significantly different at the 5-percent level.

[2] Does not include 2 days in transit.

Source: (33).

very difficult. Plants survived only 77 percent and yielded only 20 tons of marketable fruit per acre. Approximately 4 tons of fair-quality fruit were left on the plants after the last harvest. The first harvest of the stored transplants was about 15 days later than that of the nonstored.

Experiment at Leipsic, Ohio, 1965—Neither plant survival nor fruit yield was reduced when transplants were moderately clipped 17 days before harvest or when nonclipped transplants were stored for 10 days (table 19). This result was contrary to expectations because the experiments in 1964 at Bowling Green and at Swedesboro had indicated that fruit yields were

TABLE 19.—*Effect of tomato transplant storage duration and clipping on plant survival and marketable fruit yield, Leipsic, Ohio, 1965*[1]

Days in storage and clipping treatment [2]	Plant survival	Fruit yield per acre	
	Percent	Thousands	Tons
0-Moderately clipped	98	220	29.5
0-Nonclipped	99	226	3.8
5-Nonclipped	100	207	29.5
10-Nonclipped	99	202	28.0

[1] Any 2 treatment means are not significantly different at the 5-percent level.

[2] Does not include 7 days in transit and holding during unfavorable climatic and soil conditions.

Source: (29).

reduced approximately 30 percent when transplants are stored for 10 to 12 days.

Experiment at Beltsville, Md., 1965—Plant survival was not affected by N-P rate but was reduced 10 percent by 10 days of storage (table 20).

Marketable fruit yields were affected by the N-P balance. Yields were largest with either the low N and low P or the high N and high P rate (table 20). High N in the absence of the sufficient P reduced yield. The balance of N content of the transplants to P content may be considerably important for high yields in production areas in the North. However, a high N and a high P rate (at least 40 pounds of N per acre and 70 pounds of P per acre) are necessary for high transplant yield and good size uniformity in southern Georgia (24). Five days in transplant storage did not affect yields but 10 days in transplant storage reduced yields over 40 percent (table 20). This reduced yield may have been caused by reduced transplant vigor associated with an excessive proliferation of new roots during storage.

Transplant storage resulted in an accompanying delay in fruit maturity. How much of this delayed fruit maturity is due to storage *per se* and how much to delayed transplanting have not been determined.

Experiment at Beltsville, Md., 1966—Neither marketable nor total fruit yield was adversely affected by tomato transplant storage for 4 and 8 days (table 21).

Unlike transplants in the other four experiments in this study, these nonstored and stored transplants were transplanted on the same date so that all plants were grown under similar environmental conditions. This provided an opportunity to determine if the delayed fruit maturity was due to delayed transplanting or due to both delayed transplanting and storage. The number of ripe and ripening fruit before the first harvest indicated that transplant storage very likely delays fruit maturity.

TABLE 20.—*Effect of tomato transplant nutrition and storage duration on plant survival and marketable fruit yield, Beltsville, Md., 1965*[1]

Days in storage	Plant survival	Fruit yield per acre with N-P rates of—				Storage means
		20-10 pounds per acre	60-10 pounds per acre	20-90 pounds per acre	60-90 pounds per acre	
	Percent			Tons		
0 [2]	100 b	27.8	24.9	25.2	31.2	27.3 b
5 [3]	99 b	31.8	21.7	28.9	29.3	27.9 b
10 [4]	90 a	20.0	14.8	13.3	15.8	16.0 a
Nutrition mean	26.5 b	20.5 a	22.5 ab	25.4 ab	....

[1] Any 2 treatment means in the same column or row and followed by the same letter or letters are not significantly different at the 5-percent level.

[2] Does not include 3 days in transit and handling.

[3] Does not include 5 days in transit and handling.

[4] Does not include 2 days in transit and handling.

Source: (29).

TABLE 21.—Effect of tomato transplant storage duration on fruit grade and marketable fruit yield, Beltsville, Md., 1966 [1]

Days in storage [2]	Fruit yield per acre		
	Marketable	Culls	Total
	Tons		
0	19.8a	3.8a	23.6a
4	17.3a	6.1 b	23.4a
8	21.7a	5.1ab	26.8a

[1] Any 2 treatment means in the same column and followed by the same letter or letters are not significantly different at the 5-percent level.

[2] Does not include 2 days in transit and handling.

Source: (31).

Transplant Storage Summary

These five experiments indicated that tomato transplants with roots packed in moist peat moss can be stored at 50° to 55° F. without adversely affecting survival or fruit yield, provided the combined handling, transit, and storage time does not exceed 10 days. As the storage time increased, and excessive proliferation of new roots was encountered. Storage temperatures of 50° or possibly below might reduce reduce this new root proliferation. Transplant storage has value for holding marketable-sized transplants during unfavorable transplanting conditions and for insuring rapid transplant availability during favorable transplanting conditions.

Studies also indicate that transplant storage delays fruit maturity, which may be of value in scheduling harvesting.

Several reports have indicated that shipment of bare-rooted transplants does not affect their performance but does reduce labor and material cost (5, 10. 47). (See also "Mechanical Harvesting", p. 26.) The storage technique for holding marketable-sized transplants needs to be evaluated with bare-rooted transplant shipments.

Transplant Clipping

Presently (1972) field-grown tomato transplants are harvested as they attain marketable size. However, the scarcity of seasonal labor and other economic considerations are making the mechanization of this industry necessary in the South. Mechanization will require the production of large numbers of relatively uniform transplants on level land (10). Low yields and poor plant size uniformity are major obstacles to mechanical harvesting (10, 25). Recent research indicates that clipping improves plant size uniformity without adversely affecting the performance of the transplants in growers' fields in the North (10). Clipping has been reported to aid maturity and uniformity control for mechanical fruit harvesting (55).

Control clipping removes parts of the upper leaves but allows nearly all terminal buds and first flower clusters to remain intact. When the plants are 7 to 8 inches tall, a rotary mower removes about 1 inch of plant material. When additional clipping is required, 1 inch of plant material is removed either at weekly intervals or when growth rates warrant it. The mower is raised 1 inch higher than for the first clipping in order to avoid previously cut surfaces.

Moderate clipping removes terminal buds and first flower clusters but allows two or more lateral buds to remain intact. When the plants are 8 to 10 inches tall, a rotary mower removes about 2 inches of plant material (see figs. 8 and 9, pp. 48 and 49). When additional clipping is required, about 1 inch of plant material is removed. Again, the mower is raised 1 inch higher than for the first clipping in order to avoid previously cut surfaces. This degree of clipping was defined as "severe" in earlier reports (10, 23, 29) but has been redefined as "moderate" because transplant performance is not adversely affected. A minimum of 3 to 4 days between clipping and harvest are necessary to permit cut areas to heal and to permit lateral bud growth. Recommended fungicides are applied immediately after clipping.

The effect of moderate clipping on transplant size uniformity was evaluated in a field experiment (23) and a N-source and N-rate experiment in 1966 (see table 14). One experiment consisted of 42 plots, each containing four beds, in a 24- by 30-foot area (23). This experiment was percision seeded at 1,050,000 seeds of cultivar H-1350 per acre, with 97-percent germination. Seeding was on March 26, 1966, and representative areas in each plot were harvested for yield data 39 days later. Trans-

plants were classified into three categories according to size (table 1). Many transplants in this harvest were 9 to 10 inches tall. Immediately after this harvest of nonclipped transplants, all remaining transplants were moderately clipped to 6 inches with a rotary mower. Terminal buds as well as many lateral buds were cut off when the 9- to 10-inch transplants were clipped back to 6 inches. Representative areas in each plot were again harvested for yield data 14 days later. Data were analyzed statistically, and Duncan's method was used for testing comparisons between means (13).

Moderate clipping increased total marketable transplant yield by 124,000 plants per acre. Most of this increase was in the transplants in the large category (table 22). The marketable yield of 793,000 transplants per acre associated with clipping accounted for 89 percent of the total. In the N-source and N-rate experiment, moderate clipping increased the marketable transplant yield by 112,000 transplants per acre at the high N rate (table 14). The marketable yield of 814,000 transplants per acre associated with the high N rate and with clipping accounted for 90 percent of the total. Whether it would be necessary to grade out the culls, which accounted for approximately 10 percent of the total transplants, before packing remains to be studied.

Differences in type were noted between the nonclipped and the clipped transplants. The nonclipped transplants had smaller, weaker stems than the clipped. Clipped transplants with thick, strong stems would probably survive transplanting shock better than nonclipped with small, weaker stems. New lateral bud growth of the clipped transplants was from 1 to 4 inches long at harvest.

Transplant Clipping Results

The performance of field-grown clipped tomato transplants was evaluated in seven field experiments in growing areas in the North from 1965 through 1967 (29, 30, 34). Cultivar H-1350 transplants were evaluated in the four 1965 and 1966 experiments in Beltsville, Md., Leipsic, Ohio, and Swedesboro, N.J. C-17 transplants were evaluated in the 1967 experiment in New Brunswick, N.J. All transplants were moderately clipped in these five experiments. Cultivars H-1350, H-1409, C-17, Fireball, and Roma transplants were evaluated in the 1967 experiments at Beltsville and at Lafayette, Ind. Transplants were nonclipped, control clipped, or moderately clipped in these experiments. Fertilization and management of the plants were in accordance with commercial practices for each location. Multiple fruit harvests were made in all seven experiments. Data were analyzed statistically, and Duncan's multiple range test was used for testing comparisons between means (13).

Experiment at Beltsville, Md., 1965— Clipping did not significantly reduce tomato plant survival, but many of the plants that were clipped 2 days before transplant harvest were still very weak 27 days after transplanting (table 23). Clipping 2 days before transplant harvest reduced fruit yield by approximately 30 percent; whereas, clipping 14 days before transplant harvest did not reduce fruit yield. These preliminary results indicate that a certain

TABLE 22.—*Effect of moderate tomato clipping on yield and percentage of tomato transplants in a single harvest, Tifton, Ga., 1966* [1]

Treatment	Yield of transplants per acre					Percentage of transplants	
	Marketable						
	Large	Medium	Total	Culls	Total	Marketable	Cull
.... Thousands							
Nonclipping	15a	654a	669a	195 b	864a	77a	23 b
Moderate clipping ..	121 b	672a	793 b	97a	890a	89 b	11a

[1] Any 2 treatment means in the same column and followed by the same letter are not significantly different at the 5-percent level.
    Source: (23).

TABLE 23.—Effect of moderate tomato transplant clipping on plant survival and marketable fruit yield, Beltsville, Md., 1965[1]

Treatment (days clipped before transplant harvest)	Plant survival	Marketable fruit yield per acre
	Percent	Tons
0 (non clipped)	100a	31.2 b
2	92a	21.5a
14	93a	29.1 b

[1] Any 2 treatment means in the same column and followed by the same letter are not significantly different at the 5-percent level.

Source: (29).

minimum time is necessary between clipping and transplant harvest to initiate new growth and to avoid soft rot by allowing healing of the cut areas.

Experiment at Beltsville, Md., 1966—The effect of the time interval between clipping and tomato transplant harvest on performance was evaluated (30). The seeding dates had been varied in order to harvest and ship transplants of various treatments on the same date. Transplant age at shipping time ranged from 37 days for nonclipped transplants to 68 days for those clipped 16 days before transplant harvest. The lateral bud growth increased as the time interval between clipping and transplant harvest increased.

Clipping transplants did not affect plant survival, number of main fruit-bearing branches, or marketable or cull fruit yield (table 24). Fruit ripened earlier on the nonclipped plants than on the clipped. However, marketable fruit yields by harvests were not affected by clipping treatments on any of the five harvest dates. These yields averaged 1.4, 6.0, 7.6, 6.3, and 3.0 tons per acre.

Experiment at Leipsic, Ohio, 1966—This experiment was very similar to the one at Beltsville, Md., 1966 (30). Tomato transplant age at shipping time ranged from 40 days for nonclipped transplants to 52 days for those clipped 15 days before transplant harvest.

By June 22, more blossoms had appeared on the nonclipped transplants than on the clipped, and more had appeared on the transplants clipped 9 to 15 days before harvest than on those clipped 2 to 7 days before harvest (table 25). Clipping did not affect plant survival or marketable fruit yield.

Experiment at Swedesboro, N.J., 1966—Treatments in this experiment were of nonclipped tomato transplants and those clipped 2, 6, 10, and 14 days before transplant harvest (30). Transplant age at shipping time ranged from 35 days for nonclipped transplants to 66

TABLE 24.—Effect of moderate tomato transplant clipping on plant survival, fruit maturity, main fruit-bearing branches, and marketable and cull fruit yield, Beltsville, Md., 1966

Treatment (days clipped before transplant harvest)	Plant survival [1]	Fruit ripe or ripening on July 26 [2]	Main fruit-bearing branches [1]	Fruit yield per acre [1] Marketable	Cull
	Percent	Number per 25 plants	Number per plant	Tons	Tons
0 (nonclipped)	100	38 b	4.6	21.8	3.2
2	100	2a	6.5	23.0	3.5
4	99	2a	6.3	22.9	4.1
6	100	3a	6.1	20.8	4.9
8	100	6a	6.3	21.0	3.9
10	97	3a	6.3	27.6	3.9
12	99	4a	5.8	25.8	4.4
14	99	9a	6.9	27.6	2.6
16	100	11a	6.3	27.9	4.5

[1] Treatment means do not differ at the 5-percent level.

[2] Any 2 treatment means in the same column and followed by the same letter are not significantly different at the 5-percent level.

Source: (30).

TABLE 25.—*Effect of moderate tomato transplant clipping on plant survival, early blossoming, and marketable fruit yield, Leipsic, Ohio, 1966*

Treatment (days clipped before transplant harvest)	Plant survival [1]	Plants in blossom on June 22 [2]	Marketable fruit [1] yield per acre
	Percent	*Percent*	*Tons*
0 (nonclipped) ...	98	86 f	16.0
2	100	3a	15.8
5	97	7a	20.3
7	100	12 b	20.3
9	100	45 de	17.1
11	95	40 d	15.6
13	92	18 c	17.1
15	95	48 e	17.1

[1] Treatment means do not differ at the 5-percent level.

[2] Any 2 treatment means in the same column and followed by the same letter or letters are not significantly different at the 5-percent level.

Source: (30).

days for those clipped 14 days before transplant harvest.

Plant survival was 100 percent for all treatments. Marketable fruit yield was as follows:

Treatment (days clipped before transplant harvest)	Fruit yield (tons per acre)
0 (nonclipped)	16.8
2	17.1
6	17.8
10	14.7
14	16.3

The yield of marketable fruit per acre for nonclipped transplants was not significantly different from the yield for clipped transplants.

Experiment at Beltsville, Md., 1967—Tomato transplant survival was not affected by clipping-cultivar treatments; however, strong, hot, dry winds for several days immediately after transplanting reduced survival to 87 percent for the experiment (34).

Moderate clipping did not reduce marketable fruit yield for the different cultivars, whereas control clipping reduced marketable fruit yield by slightly less than 2 tons per acre (table 26). Mean marketable fruit yields of the cultivars

varied; however, cultivars reacted similarly to the various clipping treatments. Yields of Fireball were poor because this cultivar is not adapted to the Beltsville area.

Experiment at Lafayette, Ind., 1967—Tomato plant survival in these clipping-cultivar treatments was 100 percent, and fruit quality from all harvests was good and essentially 100 percent marketable (34).

Marketable fruit yields in tons per acre following moderate clipping were larger than yields following control clipping, whereas yields of nonclipped plants were intermediate (table 27). Cultivars did not differ in response to the various clipping treatments. Yields of Fireball were poor because this cultivar is not adapted to the Lafayette area.

Experiment at New Brunswick, N.J., 1967—Marketable fruit yields were reduced by tomato transplant clipping, whereas yields of culls and total fruit were not affected significantly by clipping (table 28). This reduction in marketable yield of moderately clipped C-17 transplants was unexpected because previous reports had indicated that clipped transplants perform as well as nonclipped (10, 29, 30). Some of the moderately clipped transplants had hollow shoots due to extreme moisture stress, and these

TABLE 26.—*Effect of tomato transplant clipping on marketable fruit yield of different cultivars at Beltsville, Md., 1967* [1]

Cultivar	Fruit yield per acre with—			
	Nonclipping	Control clipping	Moderate clipping	Cultivar mean per acre
	.... *Tons*			
H-1350	12.48	7.49	12.06	10.67 b
H-1409	14.72	14.18	16.00	14.97 c
C-17	16.28	14.31	17.08	15.98 c
Fireball	6.71	3.90	6.52	5.71a
Roma	23.00	23.02	22.67	22.90 d
Clipping mean	4.64 b	12.58a	14.87 b	....

[1] Any 2 treatment means in the same block and followed by the same letter are not significantly different at the 5-percent level.

Source: (34).

TABLE 27.—Effect of tomato transplant clipping on marketable fruit yield of different cultivars at Lafayette, Ind., 1967 [1]

Cultivar	Fruit yield per acre with			
	Nonclipping	Control clipping	Moderate clipping	Cultivar mean per acre
	Tons			
H-1350	27.92	26.56	28.46	27.65 b
H-1409	28.29	27.35	30.33	28.66 bc
C-17	31.56	28.28	31.55	30.46 c
Fireball	10.41	5.79	10.76	8.99a
Roma	32.07	33.46	37.62	34.38 d
Clipping mean	26.05ab	24.29a	27.74 b	....

[1] Any 2 treatment means in the same block and followed by the same letter are not significantly different at the 5-percent level.
Source: (34).

could have contributed to the poor performance of the transplants.

Transplant Clipping Summary

Tomato transplant clipping in production areas in the South can be used as a cultural practice for field holding marketable-size transplants and for improving size uniformity in order to mechanical harvest. A clipped transplant may be more desirable with its stem that is thicker and stronger than that of the nonclipped transplant and perhaps would survive transplanting shock better under adverse conditions than a nonclipped transplant.

Moderate clipping appears to be superior to control clipping when we consider plant performance in growing areas in the North. In six of seven experiments, performance of moderately clipped transplants compared favorably with that of nonclipped. A minimum of 3 to 4 days should be allowed between clipping and transplant harvesting for healing cut areas and for initiating lateral bud growth. Cultivars adapted to mechanical fruit harvesting will gradually replace those used in these experiments, and these cultivars too will need to be evaluated for transplant clipping. The major problem with clipping is the potential disease increase clipping

may cause by disseminating certain plant pathogens, and this is discussed later in this paper (see pp. 46-48).

Growth Regulators

Tomato seedlings of cultivars C-16, C-17, H-1350, Fireball, and New Yorker were treated with the growth regulator, succinic acid 2,2-dimethylhydrazide (SADH), under field conditions, then evaluated in field experiments at nine locations in growing areas in the North during the 1967 growing season (32). Runoff SADH applications were made at the third true leaf stage, and treatments with double applications were repeated 7 to 17 days later. Treatments for most experiments consisted of control and SADH at 2,500 and 5,000 parts per million in both single and double applications.

The types of transplant produced following the various SADH treatments differed considerably. Although no measurements were made, the transplants were shorter, thicker stemmed, and darker green as the SADH rate and number of applications increased.

Different types of data were collected at the various locations (32). At some locations ripe and ripening fruit and main-fruiting branches were counted. Marketable fruit yield data by weight were collected at all locations.

SADH decreased early yield of fruit in three of the nine experiments and concentrated fruit

TABLE 28.—Effect of moderate tomato transplant clipping on marketable, cull, and total fruit yield, New Brunswick, N.J., 1967

Treatment (days clipped before transplant harvest)	Fruit yield per acre		
	Marketable [1]	Culls [2]	Total [2]
	Tons		
0 (nonclipped)	24.02 b	2.80	26.82
5	20.57ab	2.99	23.56
10	17.45a	2.85	20.30
15	18.86a	3.04	21.90

[1] Any 2 treatment means in the same column and followed by the same letter or letters are not significantly different at the 5-percent level.
[2] Treatment means do not differ at the 5-percent level.
Source: (34).

maturity in two experiments *(32)*. Marketable fruit yield increased in only one experiment. SADH offers promise in scheduling tomato harvest by decreasing early yield. Additional SADH applications after transplanting would probably be necessary to obtain the desired delayed maturity. Cultivars with concentrated fruit maturity are gradually replacing cultivars used in this study, and SADH may or may not improve the concentration of fruit maturity of these new cultivars.

Mechanical Harvesting

Researchers from the Campbell Soup Company reported that mechanical harvesting of tomato transplants can be a commercial reality provided a high percentage of transplants are of marketable size at one time *(10)*. Several researchers have stressed changes in production practices that will insure high plant populations of uniform size *(10, 25)*. Mismanagement in any production practice could easily result in lack of size uniformity essential for mechanical harvesting.

More efficient handling and packaging procedures for transplants harvested by machine will be needed. Considerable savings in labor and materials required in packing and shipping would be realized if mechanically harvested transplants could be packed bare rooted directly into special crates. In 1955, Borders, Hardenburg, and Doolittle *(5)* reported that bare-

rooted tomato transplants packed in polyethylene-lined crates appeared in good condition after 2 days in transit and 4 days in storage and survived well in the field. Moran and others *(47)* found that bare-rooted tomato transplants shipped from Attapulgus, Ga., in perforated polyethylene-lined keystone crates arrived in Woodstock, Ontario, Canada, in very good condition. Survival and fruit yields from bare-rooted transplants were similar to those from transplants in standard pack. In 1966 the Campbell Soup Company reported that both nonclipped and clipped transplants can be shipped bare rooted with no adverse effects *(10)*.

Insurance Production

With the use of transplant clipping and storage and of biometeror-logical measurements to predict seeding dates, production and harvest of certified tomato transplants can be better timed to suit growers' needs in the North. Occasionally, many tomato transplants are lost in the growing areas in the North because of unexpected late freezes *(11)*. Large losses can also occur when the combined transplant handling, transit, and storage time exceeds 10 days because of extended periods of other unfavorable transplanting conditions in the North. Therefore, there must be insurance production of certified transplants to replace such losses. One suggestion has been transplant production at 250 percent of the anticipated need *(11)*.

NEMATODES

Because tomato is extremely susceptible to plant parasitic nematodes, particularly to root-knot nematodes *(Meloidogyne* spp.), transplant production holds a precarious position among crops suitable for permanent production in the sandy soils of the southeastern United States. Much of the land that is suitable for transplant production in that area is infested with one or more species of root-knot nematodes, which represent the greatest known threat to permanent tomato transplant production *(44)*.

Each year several hundred acres of tomato transplants are rejected for marketing by the Georgia Division of Entomology and Plant Industry because of root knot. Transplants that

exhibit root-knot galls represent a 100-percent loss to the grower because such plants do not meet minimum standards of Georgia Certification Regulations *(1)*. Therefore, when root knot is detected on a particular piece of land, this land becomes unsuitable for tomato transplant production *(3)*. Consequently, new land is sought, cleared of native plant growth, and brought into transplant production. If root-knot nematodes are not controlled, newly cleared land is often abandoned after only 3 to 5 years of transplant production, and the cycle is repeated *(7)*.

Plant parasitic nematodes other than root knot also can seriously reduce plant stands and

growth and thus make mechanical harvesting impractical.

Adequate nematode control is a prerequisite to continued economic production of tomato transplants in southern Georgia because of the scarcity of suitable land, the cost of "long-distance" farming, and the move toward mechanization of transplant production.

In the 1950's, research was initiated at Tifton, Ga., to develop methods for chemical control of root-knot nematodes in tomato transplants. Later the program was expanded to include studies on cultural control of root-knot and other nematodes that attack tomato. In the 1960's, studies were initiated on multiple pest control in tomato transplants, utilizing both nonselective pesticides (general soil disinfectants) and mixtures of selective pesticides (nematicide-herbicide-fungicide). Finally, studies on integrated control, using a combination of chemical and cultural methods of nematode control. were initiated.

The research program followed two broad approaches toward alleviating nematode problems in tomato transplant production. One approach was to reduce all nematode populations to either below damaging levels or, as with root-knot nematodes, below detectable levels. Below damaging levels means that nematodes are present in the soil but not in sufficient numbers to cause measurable plant damage. Below detectable levels means that the nematode cannot be recovered from the soil or detected with indicator plant. The nematode may or may not be present in the soil for below detectable levels. The second approach was to prevent nematode population from increasing to damaging levels in soils relatively free of plant parasitic nematodes.

Chemical Control of Nematodes

Root Knot

To meet Georgia Certification Standards (1), tomato transplants must be free of galls caused by root-knot nematode. From 1958 through 1968, researchers evaluated 16 nematicidal compounds for root-knot control in transplants (table 29).

In 1958. experiments were conducted on Tifton sandy loam, moderately infested with root-knot nematodes (Meloidogyne incognita (Kofoid and White) Chitwood, 1949) (18) (table 30). Three nematode-specific soil fumigants were evaluated at both the recommended and twice the recommended dosage. Liquid materials (DD and EDB) were injected 8 inches deep with chisels spaced 12 inches apart. Granular material (DBCP) was spread on the soil surface with a fertilizer applicator and incorporated in the top 6 inches of soil with a disk harrow. A drag followed fumigation in both application procedures to insure adequate soil seal. Although all chemicals increased yield of transplants, none completely controlled root knot. Control of M. incognita ranged from 66 to 97 percent. EDB (5.9 gallons per acre) controlled 91 percent of the root knot and DBCP (4 gallons per acre) controlled 97 percent. This degree of control is considered adequate for tomato fruit production (20), but not for transplant production.

TABLE 29.—Chemicals evaluated for pest control in tomato transplants 1959-68

Type of compound and code or common name	Chemical name
Nematode-specific soil fumigant:	
EDB	Ethylene dibromide; 1, 2-dibromoethane.
DD	1, 3-dichloropropene, 1, 2-dichloropropane and related C_3 compounds.
DBCP	1, 2-dibromo-3-chloropropane.
Broad-spectrum soil fumigant:	
Metham	Sodium N-methyldithio carbamate.
Dazomet	3, 5-dimethyltetrahydro 1, 3, 5, 2H-thiadiazine-2-thione.
DD-MENCS	Methyl isothiocyanate (20%) and chlorinated C_3 hydrocarbons (80%).
MBR	Methyl bromide (98%), chloropicrin (2%).
1, 3-D-PBC	1, 3-dichloropropene (80%), chloropicrin (15%), and propargyl bromide (5%).
MBR-CP-PBR	Methyl bromide (61%), chloropicrin (30%), and propargyl bromide (6.8%).
MTBG	Methyl bromide (69.125%), ethylene dibromide (4.93%), and silicon dioxide (1.25%).

TABLE . 29.—Continued

Type of compound and code or common name	Chemical name
Nonvolatile nematicide-insecticide—Continued	
Aldicarb	2-methyl-2-(methylthio) propionaldehyde 0-(methylcarbomyl) oxime.
B-25141..........	0. 0-diethyl 0-(p-(methylsulfinyl) phenyl) phosphoro thioate.
V-C 9-104........	0-ethyl S, S-dipropyl phosphorodithioate.
B-68138..........	Ethyl-4-(Methylthio)-m-tolyl isopropylphos-phoramidate.
Cynem	0. 0-diethyl 0-2-pyrazinyl phosphorothioate.
Carbofuran	2, 3-dihydro-2, 2-dimethyl-7 benzofuranol methyl-carbamate.
Disulfoton	0. 0-diethyl S-(2-(ethylthio) ethyl) phosphorodithioate.
Herbicide specific:	
Pebulate	S-propyl butylethylthiocarbamate.
Diphenamid	N, N-dimethyl-2, 2-diphenylacetamide.
CDEC............	2-chloroallyl diethyldithiocarbamate.
Propanil	3', 4'-dichloropropionanilide.
Paraquat	1, 1'-dimethyl-4, 4'-bipyridinium salts.
Trifluralin	α, α, α-trifluro-2, 6-dinitro-N, N-dipropyl-p-toluidine.
Vernolate	S-propyl dipropylthiocarbamate.
Chloramben	3-amino-2, 5-dichlorobenzoic acid.
Fungicide-specific:	
PCNB-captan......	Pentachloronitrobenzene + N-trichloromethylmercapto-4-cyclohexene-1, 2-dicarboximide.
PCNB-terrazole.....	Pentachloronitrobenzene + 5-ethoxy-3-trichloromethyl 1, 2, 4,-thiadizole.
TCNA............	2, 3, 5, 6-tetrachloro-4-nitroanisole.
DCDMB..........	1, 4-dichloro-2, 5-dimethoxybenzene.

In 1968, six nonvolatile nematicide-insecticide compounds were evaluated for nematode control in Tifton sandy loam, heavily infested with *M. incognita* (table 31). All compounds were spread on the soil surface with a fertilizer applicator and incorporated in the top 2 to 3 inches of soil with a

TABLE 30.—*Effect of nematode-specific soil fumigants on root knot and yield of tomato transplants. 1958*

Soil fumigant	Dosage per acre,[1]	Root-knot control[2]	Marketable transplants per acre[3]
	Gallons	*Percent*	*Thousands*
None	0	0	133
DD	15	66	238
DD	20	86	154
EDB	4.4	69	142
EDB	5.9	91	180
DBCP [4]	2	87	212
DBCP	4	97	183

[1] Dosage expressed as gallons of technical material.
[2] Root-knot control expressed as percent control in relation to amount of root-knot in nontreated plots.
[3] Marketable transplants based on size only.
[4] 10 percent granular formulation.
Source: *(20).*

TABLE 31.—*Effect of nonvolatile nematicide-insecticide compounds on root knot and yield of tomato transplants, 1968*

Nematicide-insecticide	Dosage per acre[1]	Root-knot control[2]	Marketable transplants per acre[3]
	Pounds	*Percent*	*Thousands*
None	0	0	310
	6	65	304
Aldicarb	9	68	310
	15	93	232
	6	61	374
B-25141	9	88	365
	15	91	304
	9	48	241
Disulfoton	13	36	368
	20	48	206
	6	94	287
Carbofuran	9	84	309
	15	86	235
	6	98	290
V-C 9-104	9	99	255
	15	99	307
	4	99	316
B-68138	6	99	275
	10	100	275

[1] Dosage expressed as pounds of active ingredient.
[2] Root-knot control expressed as percent control in relation to amount of root-knot in nontreated plots.
[3] Marketable transplants based on size only.

disk harrow. Dosages of 6, 9, and 15 pounds of active ingredient per acre were used for aldicarb, B-25141, carbofuran, and V-C 9-104. Dosages of 4, 6, and 10 pounds of active ingredient per acre were used for B-68138, and dosages of 9, 13, and 20 were used for disulfoton. Control of *M. incognita* ranged from 36 to 100 percent. Aldicarb, B-25141, disulfoton, and carbofuran did not completely control root knot at any dosage. None of these four compounds provided more than 94-percent control. V-C 9-104 appeared very promising for root-knot nematode control in transplant production. This compound approached 100-percent control at each dosage level. B-68138 was outstanding and offered the degree of control necessary for production of tomato transplants. This is exemplified by 100-percent root-knot control at 10 pounds of active ingredient per acre. Disulfoton did not sufficiently control root knot, even for tomato fruit production, which requires approximately 85-percent control *(20)*.

Multiple Pest Control

In southern Georgia, much of the land suitable for tomato transplant production is infested with destructive nematodes, weeds, and soil fungi. In 1959, we attempted to control all three pests by a single application of chemicals, thereby increasing crop efficiency and lowering production costs. Initial studies involved nematode-specific and broad-spectrum soil fumigants *(16, 19, 21)*. Later studies involved mixtures of selective pesticides *(6, 9)*.

Soil Fumigants—From 1959 through 1967, 10 soil fumigants were evaluated for control of the root-knot nematode *(Meloidogyne incognita)*; weeds—large crabgrass *(Digitaria sanguinalis* (L.) Scop.), carpetweed *(Mollugo verticillata* L.), and Florida purslane *(Richardia scabra ¯L.)*; and soil fungi— *Sclerotium rolfsii* Sacc., which causes southern blight, and *Fusarium* sp., which cause root rotting *(9, 16, 19, 21)*. Unless otherwise indicated, the chemicals were applied 6 to 18 inches deep in a single stream (or narrow band) and were covered with listed row beds that were 18 to 24 inches wide at the base and 12 inches above the original soil surface. After chemical application, row beds were not disturbed until planting, when the top 4

to 6 inches of soil was removed with a V-shaped blade. Highly volatile compounds (MBR and formulations containing MBR) were applied to the soil surface under a 4-mil polyethylene seal. The seal was removed 48 hours after chemical application. In one experiment, a chisel application (6 inches deep on 12-inch centers) of MTBG was sealed with polyethylene.

Nematode-specific soil fumigants (DD, EDB, and DBCP) did not control weeds, even at dosages in excess of that needed for nematode control (table 32). There was some indication of control of southern blight with EDB but not with DD and DBCP. Consequently, these compounds are not effective for multiple pest control.

Broad-spectrum soil fumigants, metham, dazomet, and DD-MENCS, which were injected and sealed with soil, controlled all three pests (root knot, weeds, and southern blight) to some degree (table 31).

In other tests 1,3-D-PBC controlled nematodes and promoted good plant growth but did not control weeds (table 33). Although multiple pest control obtained with these broad-spectrum soil fumigants is adequate for fresh fruit production, nematode control was not adequate for transplant production. Also, effective control of all pests requires particular attention to methods of application and soil conditions at time of application. The soil must be smooth and free of undecomposed crop residue, and the soil moisture must be from 50 to 80 percent of field capacity. The chemical must be applied 6 to 18 inches deep and sealed with 12 to 18 inches of soil, of which the top 4 to 6 inches must be removed just before planting *(19, 21)*.

Highly volatile compounds (MBR and formulations containing MBR) when applied under a polyethylene seal controlled root knot and weeds and promoted good growth of tomato transplants. However, without a polyethylene seal MTBG did not control weeds. MBR used alone controlled root knot 100 percent; however, the formulations containing MBR provided only 92- and 97- and 99-percent root-knot control.

Mixtures of Selective Pesticides— The development of nonvolatile organic phosphate and carbamate nematicides stimulated interest in multiple pest control with mixtures of selective pesticides. Such nonvolatile nematicides have

TABLE 32.—*Effect of nematode-specific and broad-sprectrum soil fumigants on root knot, weeds, and southern blight of tomato, 1959-62* [1]

Soil fumigant	Dosage per acre (48-inch row spacing) [2]	Pest control [3]		
		Root knot	Weeds [4]	Southern blight
	Pounds	*Percent*	*Percent*	*Percent*
None	0	0	0	0
Nematode specific:				
DD	99-227	50	5	0
EDB	26-60	58	10	29
DBCP	17.3	70	5	2
Broad spectrum:				
Metham	45-48	74	63	29
Dazomet	48-90	41	55	33
DD-MENCS	48.5	62	56	60

[1] Averages for 4 years for all chemicals except DBCP for 1 year, DD-MENCS for 2 years, and EDB for 3 years.
[2] Dosage expressed as pounds of active ingredient.
[3] Pest control expressed as percent control in relation to amount of root knot, weeds, or southern blight in nontreated plots.
[4] Weeds controlled were crabgrass, Florida purslane, and carpet-weed.
Source: (19).

TABLE 33.—*Effect of broad-spectrum soil fumigants on root knot, weeds, and yield of tomato transplants, 1964-67* [1]

Soil fumigant	Dosage [2] per acre	Pest control [3]		Marketable transplants per acre [4]
		Root knot	Weeds	
		Percent	*Percent*	*Thousands*
None	0	0	0	243
DD-MENCS	25 gallons	43	54	344
1, 3-D-PBC	50 gallons	81	5	486
MBR-CP-PBR [5]	217 pounds	97	78	692
MBR [5]	217 pounds	100	95	677
MTBG	210 pounds	92	0	172
MTBG [5]	210 pounds	99	96	643

[1] Averages for 1 year for all chemicals except DD-MENCS for 3 years.
[2] Dosage expressed as gallons of technical material or pounds of active ingredient on broadcast bases.
[3] Pest control expressed as percent control in relation to amount of root knot and weeds in nontreated plots.
[4] Marketable transplants based on size only.
[5] Sealed under 4-mil polyethylene for 48 hours immediately after application.
Source: (9).

been added to the soil surface and incorporated to the desired depth (6, 9).

Research was initiated in 1964 to study the efficacy of mixtures of selective pesticides in controlling nematodes, weeds, and soil fungi in tomato transplants (table 34). Experiments were made during a 4-year period in Tifton sandy loam naturally infested with root-knot nematodes, large crabgrass, Florida purslane, and the soil fungi, *Rhizoctonia solani* Kuhn and *Fusarium* sp. The nematicides cynem and aldicarb, the fungicides PCNB-captan and PCNB-terrazole, and the herbicide pebulate were applied alone and in combinations. The pesticides or pesticide mixtures were applied to the soil surface with a fertilizer applicator and incorporated either 6 to 8 inches deep with a power-driven rototiller or 3 to 4 inches deep with a disk harrow.

Although neither nematicide controlled root knot to the extent necessary for tomato transplant production, certain trends were evident and indicate promise for use of pesticide mixtures in transplant production (table 34). There was no evidence of incompatability among any of the pesticides when applied as mixtures. Root-knot control ranged from 47 to 96 percent with pesticide mixtures. Sometimes control was even better with the mixtures than with nematicides alone, particularly with aldicarb.

Weed control with pebulate alone or in mixtures was outstanding.

Increase in number of marketable transplants following treatment with PCNB-captan indicated some control of *R. solani* and *Fusarium* sp. All treatments except PCNB-terrazole alone, which was apparently phytotoxic, increased yield of marketable transplants.

Chemical Control Summary

Soil-fumigant-type nematicides did not control the root-knot nematodes to the degree necessary for tomato transplant production. Certain nonvolatile nematicides, when applied to soil surface and incorporated 3 to 4 inches deep, controlled root knot 100 percent at dosage levels that are economical for transplant production. Compounds that appear most promising are V-C 9-104 and B-68138. Although there was sufficient evidence of multiple pesticidal activity

with broad-spectrum soil fumigants, the lack of adequate root-knot control, the large amount of chemical required, and the exactness that must be exercised in application preclude their present use in tomato transplant production. Highly volatile compounds effectively controlled root knot, weeds, and soil fungi. However, the laborious application technique, the cost of materials, and the hazard in use of MBR presently (1972) limit the use of MBR in transplant production.

Mixtures of selective pesticides appear most promising for multiple pest control in tomato transplants. The herbicide pebulate controlled up to 100 percent of the weeds commonly found in transplant fields. The fungicide mixture of PCNB-captan provided sufficient protection against some soil fungi. Although the nematicides used thus far in mixtures did not control root knot adequately, more recently developed nonvolatile nematicides controlled root knot 100 percent. Compounds such as V-C 9-104 or B-68138 can be readily incorporated into mixtures with herbicides and fungicides. Such mixtures possess sufficient biological activity at minimal dosages and provide the ease and versatility of application necessary for use on large acreages. Finally, control of nematodes, weeds, and soil fungi by a single application procedure would lower unit production cost and increase the efficiency of tomato transplant production.

Cultural Control of Nematodes

Crop rotation is perhaps the oldest and most effective means of reducing populations of plant parasitic nematodes. Several crops suitable for growing in southern Georgia are reported resistant to one or more species of root-knot nematodes (18, 37, 38, 45, 54). However, there is limited information on the relation of these crops to such economically important nematodes as sting (*Belonolaimus longi-caudatus* Rau), root-lesion (*Pratylenchus brachyurus* (Godfrey) Filip and Sch. Stck.), stubby-root (*Trichodorus christiei* Allen), spiral (*Helicoty-lenchus dihystera* (Cobb) Sher), dagger (*Xiphinema americanum* Cobb), and stunt (*Tylenchorhynchus claytoni* Steiner). Although 'Coastal' bermudagrass is resistant to several species of root-knot nematode (37, 45), there is evidence that this valuable grass supports large

TABLE 34.—Effect of selective pesticides alone and in combination on root knot, weeds, and yield of tomato transplants, 1964-67 [1]

Pesticide type and chemicals	Dosage per acre [2]	Pest control [3]		Marketable transplants [5] per acre
		Root knot	Weeds [4]	
	Pounds	*Percent*	*Percent*	*Thousands*
None	0	0	0	243
Nematicide:				
Cynem [6]	8	99	0	278
Aldicarb	8	48	0	387
Fungicide:				
PCNB-captan [6]	6.7	0	25	330
PCNB-terrazole	6	0	20	246
Herbicide:				
Pebulate	3 to 4	0	84	429
Nematicide + fungicide:				
Cynem + PCNB-captan [6]	8 + 6.7	96	0	325
Aldicarb + PCNB-terrazole	8 + 6	89	26	337
Nematicide + herbicide:				
Cynem + pebulate [6]	8 + 4	89	83	327
Aldicarb + pebulate	8 + 3	47	98	505
Herbicide + fungicide:				
Pebulate + PCNB-terrazole	3 + 6	0	100	425
Nematicide + fungicide + herbicide:				
Cynem + PCNB-captan + pebulate [6]	8 + 6.7 + 4	88	90	307
Aldicarb + PCNB-terrazole + pebulate	8 + 6 + 3	62	98	474

[1] Averages for 3 years for all chemicals except treatments involving cynem and PCNB-captan for 1 year.

[2] Dosage expressed as pounds of active ingredient.

[3] Pest control expressed as percent control in relation to amount of root knot and weeds in nontreated plots.

[4] Weeds controlled were crabgrass and Florida purslane.

[5] Marketable plants based on size only.

[6] Cynem, PCNB-captan, and mixtures containing either were incorporated 6 to 8 inches deep with power-driven rototiller.

Source: (9).

populations of several ectoparasitic nematodes (17, 18, 45). Also, millet, which is commonly grown in rotation with tomato transplants, supports damaging populations of sting, root-lesion, and stubby-root nematodes (7, 18). The value of *Crotalaria* sp. as a root-knot-reducing crop has been known many years (38), but some studies show that this valuable cover crop is a good host for increase of root-lesion nematodes (7, 8, 18).

Studies were initiated in 1960 at Tifton and Cairo, Ga., to determine the effect of crop rotation, including crop sequence and length of rotations, and summer cover crops on the nematode fauna. Experimental plots were established in land that had been abandoned because of large numbers of nematodes and in recently cleared land that was relatively free of plant parasitic nematodes. The objectives were to determine if proper crop sequence would reduce nematode populations sufficiently to reclaim abandoned land for tomato transplant production and to prevent nematode increase in recently cleared land.

Crop Rotation

In 1960, an experiment was established at Cairo, Ga., in cooperation with the Research Department, Campbell Soup Company. The

experimental site was heavily infested with *Meloidogyne incognita*, *Trichodorus christiei*, *Pratylenchus brachyurus*, and *Xiphinema americanum* and, consequently, was not suitable for tomato transplant production. Six treatments, including five cover crops and clean fallow, were arranged in a randomized complete block design replicated four times. Cover crops included bahiagrass *(Paspalum notatum* Fluegge), 'Coastal' bermudagrass *(Cynodon dactylon* (L.) Pers.), marigold *(Tagetes minuta* L.), crotalaria *(Crotalaria spectabilis* Roth), and okra *(Hibiscus esculentus* L.). Each crop was grown for 6 successive years in plots in which tomato was not grown. Soil samples were taken in October each year, and a 150-cc. aliquant was processed for nematode counts.

Root-knot larvae were detected in all plots after 6 years of fallow or cover crops (table 35). *T. christiei* decreased on fallow and crotalaria but increased substantially on all other crops, particularly on marigold and bermudagrass. *P. brachyurus* increased on crotalaria and bermudagrass but decreased on the other treatments. *X americanum* increased rapidly on crotalaria, moderately on bahiagrass and bermudagrass, and relatively little on marigold and okra, but did not survive in the fallow plots. *Belonolaimus longicaudatus* was not detected when the experiment was initiated, and increased only on bermudagrass.

A similar experiment was established at Tifton, Ga., in soil infested with *B. longicaudatus*, *Helicotylenchus dihystera*, *P. brachyurus*, and *M. incognita*. Comparisons were made of the effects of 6 years of bahiagrass and 6 years of cultivated-crop rotation (corn-cotton-peanuts) on nematode population densities. After 6 years, the land was taken out of bahiagrass and cultivated-crop rotations and planted to tomato for 2 successive years.

B. longicaudatus increased more on bahiagrass than on the cultivated-crop rotation (table 36); however, *B. longicaudatus* decreased during the 1st and 2d years of tomato after 6 years of bahiagrass. *H. dihystera* and *P. brachyurus* increased on tomato after bahiagrass. *M. incognita* population was light following bahiagrass, remained light during the 1st year of tomato after bahiagrass, but developed to moderate populations during the 2d year of tomato after behiagrass. *M. incognita* population was moderate during the 1st and 2d years of tomato after the cultivated-crop rotation.

Additional rotations were studied to determine the effect of length of rotation and crop sequence on nematode population densities (table 37). Identical experiments were established at Tifton and Cairo, in soil naturally infested with *P. brachyurus*, *T. christiei*, nematode lance *(Hoplolaimus tylenchiformis* Daday), and *B. longicaudatus*. The crops used were milo *(Sorghum bicolor* (L.) Moench), crotalaria, millet *(Panicum ramosum* L.), sudangrass *(Sorghum sudanense* (Piper) Stapf), and 'Emerald' okra. Treatments consisted of 1-, 2-, and 3-year rotations. In the 1-year rotations, tomato transplants were grown every spring, followed by different cover crops or fallow during the summer. In the 2- and 3-year rotations, tomato transplants were grown every 2d and 3d year, respectively. Crotalaria or millet was grown during the years in which tomatoes

TABLE 35.—*Effect of 6 years of fallow and selected cover crops on nematode populations in tomato transplant fields, Cairo, Ga., 1960-66*

Cover crop	M. incognita	T. christiei	P. brachyurus	X. americanum	B. longicaudatus
	.... *Number per 150 cc. of soil*				
None (fallow)	11	100	2	0	0
Pensacola' bahiagrass	10	490	4	98	0
Coastal' bermudagrass	16	2,779	61	107	119
Marigold	80	1,965	1	24	0
Crotalaria	85	49	116	752	0
Okra	1,522	996	12	4	0

TABLE 36.—*Effect of 'Pensacola' bahiagrass and cultivated-crop rotation (corn-cotton-peanut) on nematode populations in tomato transplant fields, Tifton, Ga.*

Rotation	B. longicaudatus	H. dihystera	P. brachyurus	M. incognita (galling)
	...................Number per 150 cc. of soil.................			
6 years of 'Pensacola' bahiagrass 14		14	1	....
6 years of 'Pensacola' bahiagrass followed by:				
1 year of tomatoes 0		19	8	Light.
2 years of tomatoes 2		242	12	Moderate.
6 years of cultivated-crop rotation (corn-cotton-peanuts) followed by:				
1 year of tomatoes 0		1	11	Moderate.
2 years of tomatoes 0		1	8	Moderate.

Source: (17).

were not grown. Rye *(Secale cereale* L.) was grown as winter cover in some of the 2- and 3-year rotations.

Because data from both locations are similar, data from only the Cairo experiment are given in table 37. Nematode populations were extremely small initially. *P. brachyurus* and *T. christiei* were the predominant nematode species detected after 6 years of the different rotations. Generally, the numbers of *P. brachyurus* and *T. christiei* were smaller the less frequently tomato was grown in the rotation.

In the 1-year rotations, *P. brachyurus* increased substantially when either milo or crotalaria was grown as the summer cover crop (table 37). *T. christiei* increased in all plots except when crotalaria was grown as the summer cover crop or the land was fallowed.

In the 2-year rotations, the numbers of *P. brachyurus* and *H. tylenchiformis* were larger the more frequently crotalaria was grown. The numbers of *P. brachyurus* were smaller in the rotation in which millet was grown and in which the land was fallowed. The number of *T. christiei* was larger in the rotation in which millet was grown.

In the 3-year rotations, the number of *P. brachyurus* was larger the more frequently crotalaria was grown. The number of *T. christiei* was smaller the more frequently crotalaria was grown.

In all rotations, *B. longicaudatus,* which was not detected initially, was recovered most frequently in rotations in which millet was grown.

Summer Cover Crops

In Southeastern United States, the success of cover cropping depends largely on the relation of the cover crop to root-knot nematodes *(Meloidogyne* spp.). This is particularly true when a root-knot susceptible crop such as tomato follows the cover crop. Consequently, cover crops recommended for use in tomato transplant production must possess some root-knot resistance *(44).*

Root-knot resistant plant species suitable for cover crops are available *(18, 37, 38, 44, 45).* However, little is known about the relation of such root-knot resistant crops to ectoparasitic nematodes such as *Belonolaimus longicaudatus, Trichodorus christiei,* and *Pratylenchus brachyurus,* any of which can damage tomato transplants *(7, 8).* Furthermore, continued use of root-knot resistant cover crops could increase other parasitic nematodes to damaging levels. To evaluate such a possibility, experiments were established in which the total nematode fauna was studied to determine the best crops to use to suppress nematode reproduction in tomato transplant fields in southern Georgia.

Nematode populations were studied for 5 years in an experiment in which five cover crops and 'Coastal' bermudagrass were grown. The cover crops were: marigold, crotalaria, millet, beggarweed *(Desmodium tortuosum* (Sw.)DC),

and hairy indigo *(Indigofera hirsuta* L.). The experimental soil (Tifton sandy loam) was heavily infested with *B. longicaudatus, P. brachyurus, T. christiei,* and *Xiphinema americanum.* Tomato seed of cultivar H-1350 was seeded in March and transplants were harvested in May. The cover crops were planted immediately after transplant harvest and grown to maturity. This cycle was repeated five times. Soil samples (1,000 cc.) were taken during growth of tomato (April) and during growth of cover crops (September), and a 150-cc. aliquant was processed for nematode assays.

Nematode populations varied with different cover crops (fig. 1). Millet favored rapid increase of *B. longicaudatus* and *P. brachyurus.* Beggarweed and 'Coastal' bermudagrass favored increase of *B. longicaudatus* but not of *P. brachyurus* and *T. christiei.* Hairy indigo and crotalaria favored increase of *P. brachyurus* but not *B. longicaudatus.* None of the nematode species present increased to an appreciable extent on marigold.

Populations of all nematode species were much smaller during the early-season growth of tomato transplants than they were during growth of cover crops in the summer. Transplant yield was significantly related to nematode population, particularly to *B. longicaudatus* (table 38). Yield was best in plots in which marigold, hairy indigo, and crotalaria had grown.

Three cover crops (crotalaria, marigold, and beggarweed) were evaluated in the greenhouse for reaction to root-knot nematode species, including *M. javanica* Chitwood, *M. incognita, M. incognita acrita, M. arenaria* Chitwood, and *M. hapla* Chitwood (table 39). Each crop was grown for 6 weeks in soil artificially infested with each nematode species. Afterwards, plants were dug and roots were rated for galling and stained for observations of nematodes. Crotalaria prevented the reproduction of all root-knot species used. *M. hapla* caused some galling of crotalaria roots, but no egg-laying females were observed. Marigold prevented the reproduction

TABLE 37.—*Effect of length of rotation and crop sequence on nematode populations in tomato transplant fields, Cairo, Ga., 1960-65*

| Length of rotation and crop sequence	P. brachyurus	T. christiei	H. tylenchiformis	B. longicaudautus
	.... Number per 150 cc. of soil			
One year:				
Tomato-milo	117	228	1	0
Tomato-crotalaria	145	13	0	0
Tomato-millet	53	113	1	1
Tomato-sudangrass	40	125	0	0
Tomato-okra	12	147	0	0
Tomato-fallow	5	27	0	0
Two years:				
Crotalaria - Tomato + crotalaria + rye.[1]	142	11	25	0
Crotalaria - Tomato + crotalaria.	91	6	0	0
Crotalaria - Tomato + fallow.	25	6	0	0
Crotalaria - Tomato + millet + rye.[1]	18	41	1	11
Three years:				
Crotalaria + rye[1] - Crotalaria - Tomato + crotalaria + rye.[1]	76	4	2	1
Crotalaria + rye[1] - Crotalaria + rye[1] - Tomato + millet + rye.[1]	55	42	6	1

[1] Rye grown as winter cover.
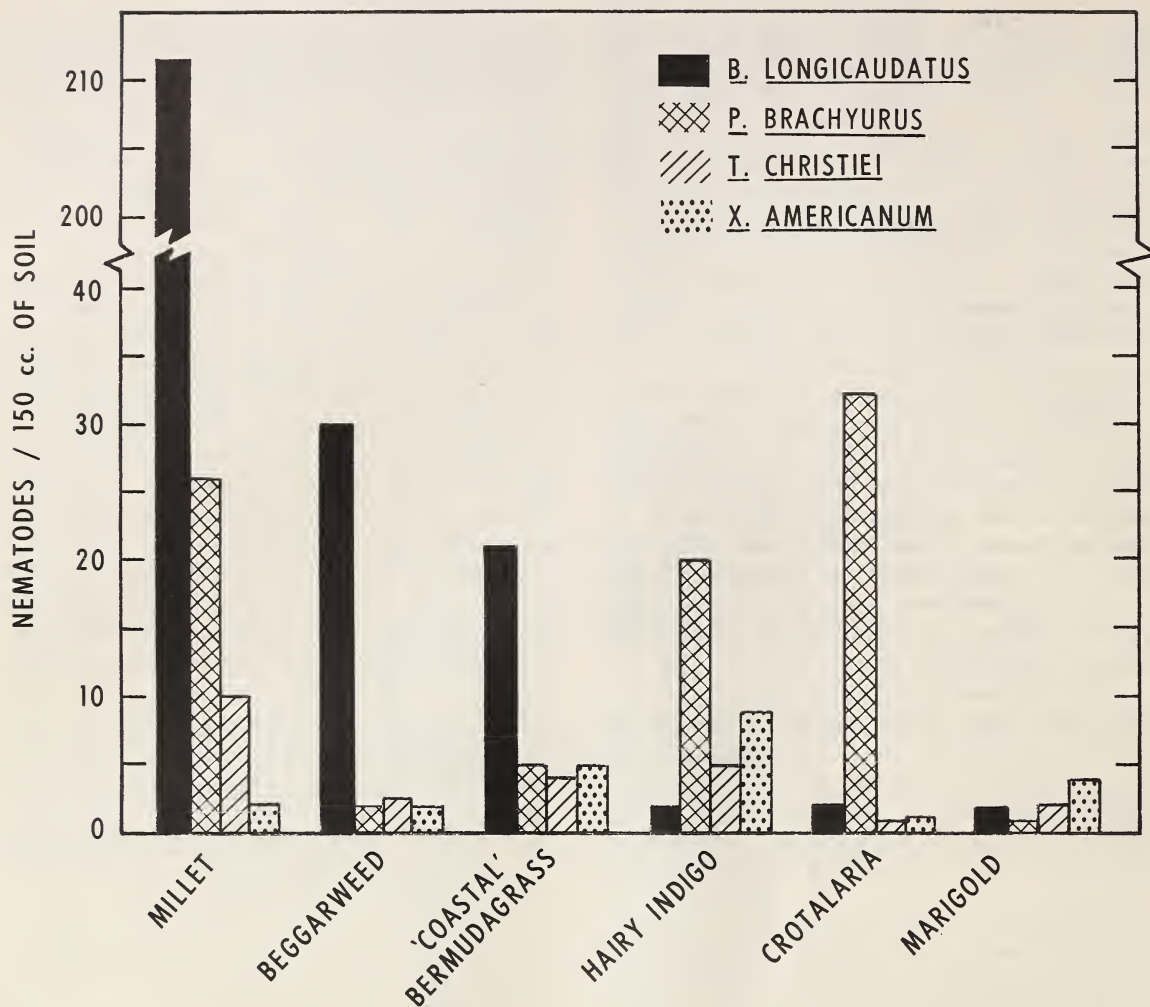
FIGURE 1.—Five-year average number of nematodes recovered from soil in which different cover crops were grown.

of all species except *M. javanica*, *M. arenaria*, and *M. hapla*, which reproduced readily with marigold. Beggarweed prevented the reproduction of all species except *M. hapla*. Tomato supported reproduction of all root-knot species observed.

In 1964, an experiment was established in recently cleared land that was relatively free of most plant parasitic nematodes. Small numbers of *Tylenchorhynchus claytoni* Steiner, *P. brachyurus*, *T. christiei*, *X. americanum*, and *Helicotylenchus dihystera* were present. Seven

cropping systems were arranged in a randomized complete block design replicated six times. The cover crops, cotton *(Gossypium hirsutum* L.), sudangrass, millet, crotalaria, beggarweed, marigold, and hairy indigo were planted in the plots in May of each year for 5 years. In March of every 3d year, tomato seed of cultivar H-1350 were seeded in each plot. After tomato transplant harvest, cover crops were seeded.

Soil samples (1,000 cc.) were taken for nematode assays each year during growth of the cover crops.

TABLE 38.—*Effect of cover crops on nematode populations in tomato transplant fields and yield of tomato transplants, Tifton, Ga., 1963-67* [1]

Cover crop	B. longicaudatus	P. brachyurus	Marketable transplants per acre
	Number per 150 cc. of soil		*Thousands*
Marigold	0.8	0.4	237
Hairy indigo	7.6	2.2	197
Crotalaria	1.3	9.3	185
Bermudagrass	15.0	5.8	163
Beggarweed	25.6	3.6	82
Millet	40.9	19.6	54
LSD 0.05	25.0	n.s.	73

[1] Data are averages for 6 years.
Source: (7).

Initial populations of plant parasitic nematodes were extremely small. Certain species that were later recovered were not even detected when the experiment was established. Time required for different species to reach detectable levels varied with nematode species and cover crops.

P. brachyurus was detected at the end of 1 year of sudangrass, millet, crotalaria, and cotton. At the end of 5 years, *P. brachyurus* had increased 100-fold on sudangrass and millet and 75-fold on crotalaria and cotton (fig. 2). *P. brachyurus* was not detected until the end of 3 years of hairy indigo, beggarweed, and

marigold; thereafter numbers of *P. brachyurus* detected were extremely small in plots in which these crops were grown.

T. claytoni was detected at the end of 5 years of sudangrass and beggarweed. At the end of 5 years, *T. claytoni* had increased 150-fold on sudangrass and 50-fold on beggarweed (fig. 3). *T. claytoni* was detected in very small numbers at the end of 2 years of crotalaria, marigold, hairy indigo, millet, and cotton; thereafter it was not detected in plots in which these crops were grown.

X americanum was detected at the end of 1 year of marigold. At the end of 5 years, *X.*
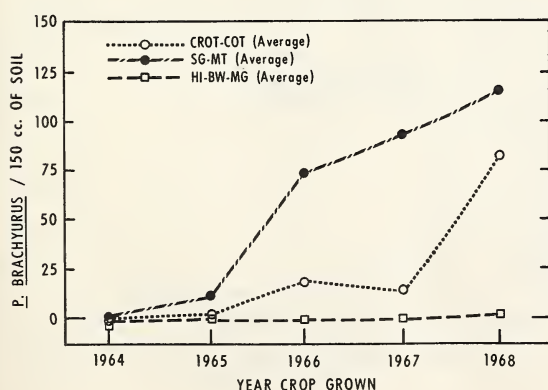
FIGURE 2.—Population development of *Pratylenchus brachyurus* as influenced by cover crop and time. SG-sudangrass, MT-millet, CROT-crotalaria, COT-cotton, HI-hairy indigo, BW-beggarweed, MG-marigold. Crops from which nematode counts were similar are grouped.
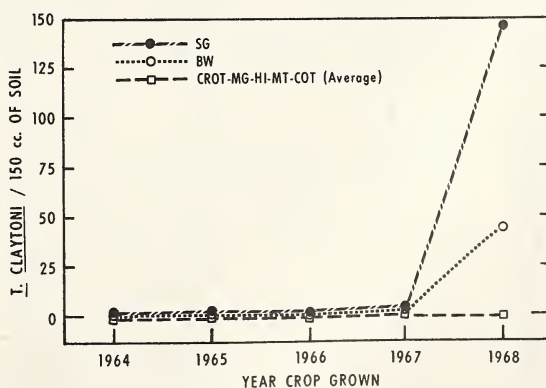
FIGURE 3.—Population development of *Tylenchorhynchus claytoni* as influenced by cover crop and time. SG-sudangrass, MT-millet, CROT-crotalaria, COT-cotton, HI-hairy indigo, BW-beggarweed, MG-marigold. Crops from which nematode counts were similar are grouped.

TABLE 39.—Effect of cover crops and tomato on reproduction and infection of root-knot nematodes (Meloidogyne spp.) populations, Auburn, Ala.[1]

Cover crop	M. javanica		M. incognita		M. incognita acrita		M. arenaria		M. hapla	
	Reproduction	Infection	Reproduction	Infection	Reproduction	Infection	Reproduction	Infection	Reproduction	Infection
	Percent									
Crotalaria	0	5	0	8	0	5	0	0	0	68
Marigold	5	3	0	3	0	3	100	100	100	45
Beggarweed	0	0	0	0	0	0	0	0	100	85
Tomato (check)	100	100	100	98	100	83	100	100	100	70

[1] Percent reproduction indicates amount of egg-laying females; percent infection indicates amount of galling of cover crops in relation to amount of galling of tomatoes.

Source: (18).

americanum had increased 75-fold on marigold (fig. 4). *X americanum* was detected at the end of 1 year of hairy indigo, millet, and cotton, but had increased less than 10-fold on these crops at the end of 5 years. At the end of 5 years, *X americanum* was detected in very small numbers in plots in which sudangrass and crotalaria had grown, but not at all in plots in which beggarweed had grown.

T. christiei was detected at the end of 1 year of all crops except hairy indigo. At the end of 5 years, *T. christiei* had increased 75-fold on sudangrass and cotton and 25-fold on hairy indigo, millet, and beggarweed (fig. 5). *T. christiei* did not increase on marigold and crotalaria.

H. dihystera was detected in very small numbers at the end of 3 years of all crops. At the end of 5 years, *H. dihystera* had increased 500-fold on crotalaria and hairy indigo, 150-fold on cotton and millet, and 50-fold on sudangrass, marigold, and beggarweed (fig. 6).

Transplant yield and size uniformity varied with different cover crops. The number of marketable transplants was highest after 2 years of crotalaria and hairy indigo and lowest after 2 years of sudangrass and cotton (table 40). Size uniformity, as measured by percent marketable transplants, was highest after 2 years of
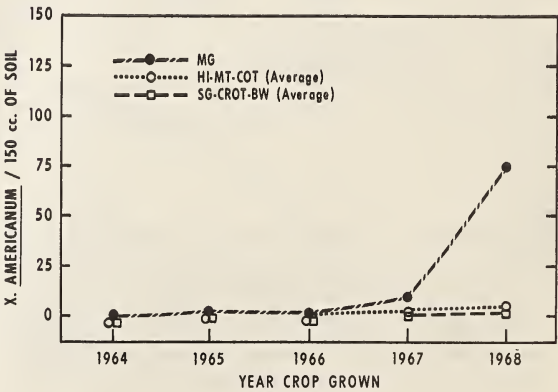

FIGURE 4.—Population development of *Xiphinema americanum* as influenced by cover crop and time. SG-sudangrass, MT-millet, CROT-crotalaria, COT-cotton, HI-hairy indigo, BW-beggarweed, MG-marigold. Crops from which nematode counts were similar are grouped.

crotalaria and hairy indigo and lowest after sudangrass.

Cultural Control Summary

Fallow was by far the most effective means of reducing nematode populations. However, even after 6 years of clean fallow, root-knot
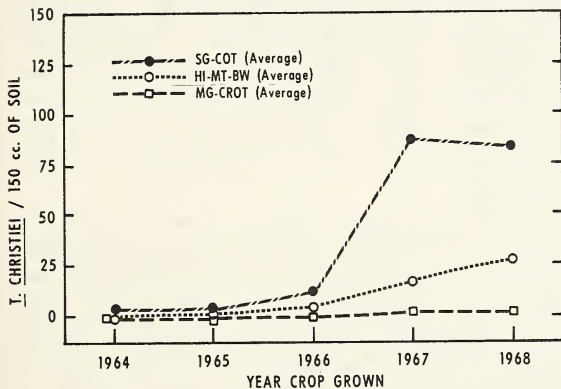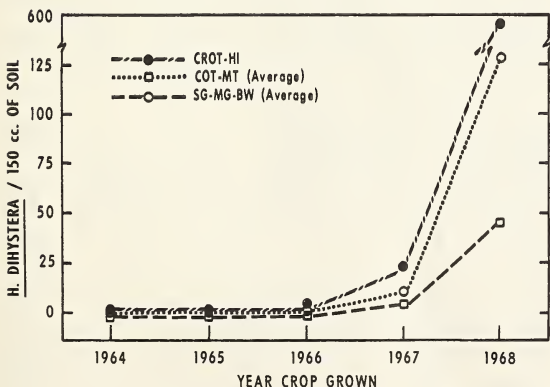

FIGURE 5.—Population development of *Trichodorus christiei* as influenced by cover crop and time. SG-sudangrass, MT-millet, CROT-crotalaria, COT-cotton, HI-hairy indigo, BW-beggarweed, MG-marigold. Crops from which nematode counts were similar are grouped.

FIGURE 6—Population development of *Helicotylenchus dihystera* as influenced by cover crop and time. SG-sudangrass, MT-millet, CROT-crotalaria, COT-cotton, HI-hairy indigo, BW-beggarweed, MG-marigold. Crops from which nematode counts were similar are grouped.

TABLE 40.—*Effect of cover crops on tomato transplant yield and size uniformity as influenced by 2 years of cover crops, Tifton, Ga., 1966* [1]

| Cover crop | Yield of transplants per acre, | | Marketable transplants |
	Marketable	Cull	
	Thousands	*Thousands*	*Percent*
Crotalaria	775 c	134a	85 b
Hairy indigo	770 c	125a	86 b
Millet	731 bc	132a	85 b
Beggarweed	742 bc	150a	83ab
Marigold	727 bc	157a	82ab
Sudangrass	665a	182a	79a
Cotton	712ab	142a	83ab

[1] Any 2 treatment means in the same column and followed by the same letter or letters are not significantly different at the 5-percent level.

Source (8).

nematodes were detected from soil samples. None of the cover crops reduced root-knot nematodes to a level adequate for tomato transplant production. In soil in which root-knot nematodes were not present, marigold, crotalaria, and hairy indigo reduced *Belonolaimus longicaudatus, Pratylenchus brachyurus,* and *Trichodorus christiei* sufficiently to allow for economic transplant production. Rotations in which transplants were grown every 2 or 3 years were slightly more effective in reducing nematode populations than were rotations in which transplants were grown every year.

Recently cleared land was kept relatively free of plant-parasitic nematodes when certain cover crops were grown. Marigold, crotalaria, and hairy indigo prevented increase of such important nematodes as *T. christiei* or *P. brachyurus*. However, no one cover crop prevented increase of all nematodes studied. Crops such as millet, 'Coastal' bermudagrass, sudangrass, and cotton rapidly increased *T. christiei, B. longicaudatus,* and *P. brachyurus.* Consequently, the use of these crops as summer cover crops in tomato transplant fields would hasten the abandoment of recently cleared land for tomato transplant production.

Increase of nematodes was evidence by both reduced transplant yield and reduced size

uniformity. Therefore, preventing nematode population increase, to detectable level in the case of root-knot nematodes and to damaging levels in the case of other plant-parasitic nematodes, is a prerequisite to economical production of tomato transplants.

Integrated Control Program

Previous studies indicate that, with rare exceptions, neither chemical nor cultural means of nematode control provide the degree of root-knot nematode control necessary to reclaim abandoned land for tomato transplant production. Although near 99-percent root-knot control was obtained by either method, this does not meet minimum standards of Georgia certification regulations. Furthermore, clean fallow, which adequately controlled root-knot nematodes, depletes soil organic matter and increases erosion. Finally, continuous use of certain cover crops, while reducing or preventing the increase of certain nematode species, may provide a favorable environment for increase of other economically important species.

In 1965, research was initiated to study the efficacy of combination chemical and cultural means of nematode control. In addition to providing more adequate nematode control, such integrated control programs could provide more efficient use of land by allowing production not only of tomato transplants but also of other cash crops.

Rotation-Chemical Treatment

An experiment was established in soil heavily infested with *Trichodorus christiei* and *Meloidogyne incognita*. Five crops and fallow were evaluated for their ability to reduce these nematode species. After 6 years of crop growth or fallow, the plots were subdivided, treated with nematicidal chemicals, and planted to tomatoes. Granular chemicals (aldicarb and V-C 9-104) were spread on the soil surface with a fertilizer applicator and incorporated in the top 3 to 4 inches of soil with a disk harrow. Liquid chemicals (DBCP, EDB, and DD-MENCS) were injected 6 inches deep on 8-inch centers. Granular chemicals were applied just before planting, whereas liquid chemicals were applied 2 weeks before planting. All chemicals were applied as broadcast treatments. Soil samples for nematode analysis were taken just before and 4 weeks after chemical application. Six weeks after planting, 100 tomato plants were dug from each plot and examined for root knot.

Nematode counts from soil samples taken before chemical application revealed that none of the crops nor fallow had reduced *T. christiei* below detectable levels. Examination of tomato roots revealed that *Meloidogyne* spp. infestation was light following 6 years of marigold, crotalaria, and fallow; moderate following 'Coastal' bermudagrass and 'Pensacola' bahiagrass; and heavy following okra (table 41). Fallow was by far the best nematode-reducing treatment.

Treatment with aldicarb or V-C 9-104 following all crops and fallow substantially reduced *T. christiei* and reduced *Meloidogyne* spp. below detectable levels. Treatment with DBCP, EDB or DD-MENCS substantially reduced *T. christiei* and reduced *Meloidogyne* spp. below detectable levels only following 6 years of marigold, crotalaria, or fallow.

Fallow-Cover Crop

Previous studies showed that clean fallow adversely affects many nematode species. The effectiveness of fallow in reducing nematode populations is enhanced by periods of severe drought that usually occur during May and June, immediately after transplant harvest.

An experiment was established in 1966 to study the efficacy of fallow and cover crops alone and in combinations in reducing nematode population. Six cover crops and fallow alone and in combinations were arranged in a randomized complete block design in soil naturally infested with *Trichodorus christiei*, *Pratylenchus brachyurus*, and *Meloidogyne incognita*. Plots that received both fallow and a cover crop were fallowed for 6 weeks immediately following tomato transplant harvest and then planted to the cover crop. Plots that received only cover crops were planted to the cover crops immediately following transplant harvest. Soil samples (1,000 cc.) for nematode counts were taken and processed for nematode counts in September, during the growth of the cover crops.

Fallow and crotalaria suppressed populations

TABLE 41.—*Effect of cover crops alone and in combination with chemical soil treatment on Trichodorus christiei and Meloidogyne spp., Tifton, Ga.*

Treatment	Dosage per acre [1]	T. christiei Number per 150 cc. of soil	Meloidogyne spp. (galling)
6 years of marigold		8	Light.
6 years of marigold followed by:			
aldicarb	10 pounds	0	None.
V-C 9-104	10 pounds	0	Do.
DBCP	4 gallons	0	Do.
EDB	5 gallons	0	Do.
DD-MENCS	30 gallons	0	Do.
6 years of crotalaria		12	Light.
6 years of crotalaria followed by:			
Aldicarb	10 pounds	0	None.
V-C 9-104	10 pounds	0	Do.
DBCP	4 gallons	7	Do.
EDB	5 gallons	0	Do.
DD-MENCS	30 gallons	0	Do.
6 years of fallow		0	Light.
6 years of fallow followed by:			
Aldicarb	10 pounds	0	None.
V-C 9-104	10 pounds	2	Do.
DBCP	4 gallons	5	Do.
EDB	5 gallons	0	Do.
DD-MENCS	30 gallons	0	Do.
6 years of 'Coastal' bermudagrass.		21	Moderate
6 years of 'Coastal' bermudagrass followed by:			
Aldicarb	10 pounds	3	None.
V-C 9-104	10 pounds	0	Do.
DBCP	4 gallons	34	Light.
EDB	5 gallons	37	Do.
DD-MENCS	30 gallons	61	Do.
6 years of 'Pensacola' bahiagrass.		2	Moderate.
6 years of 'Pensacola' bahiagrass followed by:			
Aldicarb	10 pounds	0	None.
V-C 9-104	10 pounds	5	Do.
DBCP	4 gallons	4	Light.
EDB	5 gallons	10	Do.
DD-MENCS	30 gallons	29	Do.
6 years of okra		5	Heavy.
6 years of okra followed by:			
Aldicarb	10 pounds	0	None.
V-C 9-104	10 pounds	0	Do.
DBCP	4 gallons	14	Moderate.
EDB	5 gallons	6	Do.
DD-MENCS	30 gallons	19	Do.

[1] Dosage expressed as pounds of active ingredient or gallons of technical material.

of all nematode species (table 42). All species increased on corn, millet, and okra. *T. christiei* and *P. brachyurus* increased also on velvet bean and soybean. Six weeks of fallow between transplant harvest and planting of cover crops effectively suppressed increase of all nematode species. This was particularly striking when 6 weeks of fallow preceded corn or crotalaria. All species increased rapidly when corn was planted immediately after transplant harvest.

Integrated Control Summary

Combination chemical and cultural means of nematode control show promise of providing the degree of root-knot nematode control (100 percent) necessary for permanent production of tomato transplants on the same land. When either means alone did not adequately control root knot, combination treatments such as cover crop plus aldicarb or V-C 9-104 reduced root knot to below detectable levels.

Also, clean fallow between transplant harvest

TABLE 42.—*Effect of fallow and cover crops alone and in combination on nematode populations in tomato transplant fields, Tifton, Ga., 1966-68*

Treatment	T. christiei		P. brachyurus		M. incognita	
	1966	1968	1966	1968	1966	1968
	Number per 150 cc. of soil					
Fallow	1	3	2	0	0	0
Crotalaria	0	1	1	75	0	0
Corn	4	94	54	145	0	22
Millet	3	4	1	1	0	1
Okra	1	5	8	19	0	25
Velvet bean	2	2	32	147	0	0
Soybean	9	1	90	11	0	0
Fallow-corn	1	2	2	1	0	8
Fallow-crotalaria	1	0	1	0	0	0
Fallow-millet	1	1	1	0	0	13

and planting of summer crops prevented increase of root-knot nematodes and shows promise of more efficient utilization of land by allowing production not only of tomato transplants but also of additional cash crops, such as corn.

WEED CONTROL

Weeds must be adequately controlled throughout the year in order to prevent problems in the tomato crop. A typical system might include: (1) Use of appropriate herbicides in the tomato transplant crop *(15, 56, 57)*; (2) clean cultivation until establishment of the cover crop; (3) use of herbicides or tillage to maintain a weed-free cover crop; and (4) maintenance of the cover crop stand until frost or next planting *(59)*.

Weed control research in direct-seeded tomatoes for the production of transplants has been in progress since 1962 at Tifton, Ga. During 1962 and 1963, similar experiments were conducted, using herbicides applied preplant, preemergence, delayed preemergence, and postemergence on a Tifton loamy sand *(56)*. Direct-seeded tomatoes were tolerant to *S*-propyl butylethylthiocarbamate (pebulate), as a preplant treatment at 2 to 4 pounds per acre, and *N*, *N*-dimethyl-2,2-diphenylacetamide (diphenamid), as a preemergence treatment at 2.5 and 5 pounds per acre. Pebulate at 4 pounds per acre caused some crop injury and

diphenamid gave erratic control of broad-leaved weeds (table 43). Direct-seeded tomatoes were tolerant to 2-chloroallyl diethyldithiocarbamate (CDEC), applied preemergence, but not to 3',4'-dichloropropionanilide (propanil), applied postemergence at rates over 1.5 pounds per acre. CDEC and propanil were erratic in the degree of weed control obtained.

Other tests were conducted from 1963 through 1965 on several delayed preemergence treatments on tomatoes *(57)*. Diphenamid, applied preemergence, was included as a standard for comparison. Delayed preemergence applications of diphenamid showed equivalent degrees of weed control even when some weeds had emerged. The emerged weeds showed growth suppression, which kept them from competing with the crop.

Weed control by propanil was somewhat erratic. At 1.5 pounds per acre, propanil was not uniformly effective and performance appeared to be influenced by the environmental conditions at the time of application. The 3-pounds-per-acre rate was more effective than the 1.5-pounds-per-

TABLE 43.—Effect of various herbicides on weed control and crop tolerance in seeded tomatoes, 1963

Type of treatment and treatment	Rate per acre	Weed control at 4 weeks		Crop tolerance [1]
		Broadleaved weeds	Grass	
	Pounds	*Percent*	*Percent*	
Preplant incorporate:				
Pebulate	2.0	94	94	9.3
Do	4.0	99	100	8.4
Pebulate + cultivation	4.0	100	100	7.9
Pebulate	8.0	100	100	7.0
Preemergence:				
Diphenamid	2.5	13	81	9.9
Do	5.0	64	59	9.4
Diphenamid + cultivation	5.0	97	98	9.9
Diphenamid	10.0	76	100	8.8
CDEC	6.0	54	71	9.4

[1] Average of 3 ratings during season: 0 = plants killed; 10 = no effect.
Source: *(56)*.

acre rate. The increased effectiveness could be attributed to either better contact action or a slight residual activity.

A mixture of propanil and diphenamid was evaluated so that the desirable properties of both compounds could be combined. The mixture increased the crop injury when compared with injury caused by either compound applied alone.

The herbicide, 1,1'-dimethyl-4,4'-bipyridinium salts (paraquat) produced excellent contact action on emerged weeds but showed no residual activity. Paraquat alone was not adequate due to competition from weeds that emerged after the herbicide was applied. The mixture of paraquat and diphenamid varied in its effectiveness from year to year.

Taylorson studied the effects of diphenamid and pebulate treatments on sugars, total nitrogen (N), and total phosphorus (P) of tomato transplants *(58)*. The roots, stems, and leaves were analyzed separately. Samples from the weedy check were generally high in sugars. The recommended rates of diphenamid and pebulate did not change the sugar concentration of tomato transplants when compared with that of the handweeded check. The N concentration in the roots and stems was high in the tomato transplants treated with pebulate. Other plant parts were not affected by any treatment. The P

concentration also was not affected by any treatment. The results of these analyses suggest that the presently (1972) recommended herbicide treatments do not appreciably alter the sugar, N, or P concentrations of the harvested tomato transplants.

During 1965, herbicides were evaluated on crotalaria, which may be used as a cover crop, by Taylorson, Jaworski, and Murphy *(59)*. They determined that α, α, α,-trifluro-2,6-dinitro-N, N-dipropyl-*p*-toluidine (trifluralin), S-propyl dipropylthiocarbamate (vernolate), 3-amino-2,5-dichlorobenzoic acid (chloramben), and diphenamid can be utilized effectively in the establishment of crotalaria as a cover crop.

During 1967, studies at Tifton *(15)* showed that 2 pounds per acre of pebulate and 5 pounds per acre of diphenamid yielded the highest number of marketable tomato transplants. The marketable transplants per acre from these treatments were 309,800 and 296,000, respectively. Other promising compounds are the methyl ester of chloramben and CDEC. However, some stunting of the tomatoes was evident in plots treated with the methyl esters of chloramben and the weed control following CDEC treatment is somewhat erratic from year to year.

DISEASES

Diseases have been major limiting factors in the production of field-grown tomato transplants since the beginning of the transplant industry in southern Georgia in the early 1900's. Historically, early blight caused by *Alternaria solani* (Ell. and G. Martin) Sor., bacterial wilt caused by *Pseudomonas solanacearum* (E. F. Sm.) E. F. Sm., southern blight caused by *Sclerotium rolfsii* Sacc., bacterial spot caused by *Xanthomonas vesicatoria* (Doidge) Dows., and late blight caused by *Phytophthora infestans* (Mont.) dBy. have been the most serious diseases in transplant fields.

Of these five diseases, early blight has been the most destructive. Although its severity has decreased with the advent of more effective fungicides, better spray equipment, and more adequate fertilization, early blight continues to be the most damaging disease on transplants *(53)*.

Bacterial wilt and southern blight continue to cause considerable damage and are discussed in detail in this section.

The incidence of bacterial spot has been drastically reduced, apparently through the use of disease-free seed and by strict adherence to the practice of treating seed with mercurial compounds, which has been required by the Georgia Department of Agriculture for certification of transplants *(1)*. However, use of most mercurial compounds as seed treatments has been restricted by the U.S. Environmental Protection Agency and use of nonmercurial compounds are now required. Bacterial spot will be discussed in detail beginning on page 50.

According to Ratcliffe and Morton *(53)*, late blight has not been reported on tomato transplants in Georgia since 1946.

Since 1966, a seedling blight and stem rot caused by *Pythium aphanidermatum* (Edson) Fitz. has become a serious problem in some transplant fields. This disease will be discussed in detail on page 50.

Although tobacco mosaic virus (TMV) has occurred infrequently in transplants, it is a potential threat to transplant production. Research work on this disease is discussed on page 52.

At present (1972), the trend is away from extensive transplant culture involving large acreages of recently cleared land to a more intensive culture involving fewer acres of cultivated land. Several years will be needed to evaluate the impact of this new type of culture on the incidence of various diseases.

This publication summarizes the results of research on diseases of tomato transplants that has been conducted in Georgia since about 1960.

Bacterial Wilt

Considerable research has been conducted on bacterial wilt because it is one of the most persistent diseases in tomato transplant fields. Bacterial wilt is caused by the soilborne pathogen *Pseudomonas Solanacearum*.

Vertical Distribution of Pseudomonas solanacearum

Information on the vertical distribution of *P. solanacearum* in the soil was needed to provide a better basic understanding of the causal organism and to predict the efficacy of various chemicals for control *(39)*. From 1966 through 1968, we collected soil samples from eight tomato transplant fields located in southern Georgia and known to be infested with *P. solanacearum* (table 44). Soil samples were collected separately in 6-inch increments to a depth of 36 inches. The presence of the bacterium in the soil was determined by transplanting susceptible tomato plants into soil collected from the various depths.

The bioassays of the soils showed high infestations of *P. solanacearum* in the top 12 inches in soils collected from five locations (soil samples 2, 3, 4, 7, and 8 in tables 44 and 45). In these five soils, the level of infestation dropped markedly or was not detectable in the 12- to 18-inch zone and the bacterium was not found deeper than 12 to 18 inches except for an extremely low infestation in soil sample No. 4. In soil sample No. 5 the bacterium was not found in the top 6 inches, but a low infestation occurred in all other layers through the 24- to 30-inch zone. The organism was not detected in soil samples No. 1 and No. 6. Generally, the time needed for expression of severe wilt symptoms varied among soils and usually increased with depth (table 45).

The time needed varied from 19 days in soil from the 0- to 6-inch zone of soil sample No. 2 to 104 days in soil from the 18- to 24-inch zone of sample No. 5. Vertical distribution varied somewhat with location but was not correlated with soil type. The absence of the bacterium in the top 6 inches of soil sample No. 5 was probably the result of the dryness of the soil at the time the sample was taken. The apparent absence of the bacterium in soil samples No. 1

and No. 6 shows the erratic horizontal distribution in a known infested field.

These results on vertical distribution indicate that a fumigant or other chemical that would destroy the wilt bacterium to a depth of 12 inches would eliminate most of the population in the soil profile. A low level of infestation apparently occurs deeper than 12 inches in certain soils and this could result in reinfestation of fumigated surface layers.

TABLE 44.—*Character of 8 soils in Georgia used to determine the vertical distribution of* P. solanacearum *in soil*

Soil sample No.	Date collected	Location (county)	Soil type [1]	Soil pH [2]	
				Initial	Final
1	Aug. 2, 1966	Tift	Stilson Loamy sand (Goldsboro).	4.6	7.0
2	do	do	Leefield loamy sand (Klej).	4.8	7.4
3	Sept. 7, 1967	do	Fuquay loamy sand (Norfolk).	4.6	6.8
4	Sept. 13, 1967	do	Stilson loamy sand (Goldsboro).	5.0	6.7
5	Oct. 3, 1967	Colquitt	Leefield loamy sand (Lynchburg).	4.5	7.3
6	Oct. 16, 1967	Berrien	Robertsdale loamy sand (Irvington).	4.6	6.9
7	May 9, 1968	do	Stilson loamy sand (Goldsboro).	4.9	7.1
8	Aug. 10, 1968	Tift	Leefield loamy sand (Klej).	4.5	7.2

[1] The soils are classified according to the Seventh Approximation System. The earlier designation is shown in parentheses.

[2] The initial and the final pH reading was taken at the time the soil was collected and the final at the end of the studies.

Source: *(39)*.

TABLE 45.—*Tomato plants killed by* P. solanacearum *and average number of days for symptom expression in plants transplanted into soil collected from various depths, 1966-68*

Soil sample No.	Tomato plants killed in soil collected from depths of.[1]—					
	0-6 inches	6-12 inches	12-18 inches	18-24 inches	24-30 inches	30-36 inches
	.... *Percent (days)*					
1	0	0	0	0	0	0
2	75(19)	60(31)	10(59)	0	0	0
3	90(37)	50(39)	20(69)	0	0	0
4	95(47)	85(57)	30(74)	5(101)	0	0
5	0	30(92)	20(74)	20(104)	15(91)	0
6	0	0	0	0	0	0
7	95(39)	50(46)	0	0	0	0
8	80(24)	40(37)	0	0	0	0

[1] The first value refers to the percentage of kill (20 plants were used in soil from each depth). The numbers in parentheses are the average number of days before the appearance of severe wilt symptoms.

Source: *(39)*.

Susceptibility of South American Marigold to Bacterial Wilt

South American marigold *(Tagetes minuta)* has been suggested for control of certain plant-parasitic nematodes because this crop sometimes increases yields of marketable tomato transplants when used as a cover crop *(8)*. However, in a host-range study, Dukes, Morton, and Jenkins *(12)* found *T. minuta* to be susceptible to *P. solanacearum*. Because marigold was susceptible to wilt, these workers suggested that caution be used in planting this crop in rotation with susceptible crops such as tomatoes, which bacterial wilt has been known to damage.

Studies on the Spread of Pseudomonas solanacearum by Clipping

In recent years tomato transplant clipping has been used to improve size uniformity and to regulate harvest schedules to meet the needs of growers in the North. Although no obvious disease problems have resulted from transplant clipping in Georgia, we were concerned about the possible spread of plant pathogens, especially bacteria and viruses, by clipping, and we initiated work to assess the danger involved *(40)*.

In the greenhouse, we used scissors to simulate the different degrees of clipping that occur when transplants are clipped in the field. Bacterial spread was studied by first clipping a diseased plant then a healthy plant (6 to 8 inches tall). *P. solanacearum* was spread quite readily from diseased to healthy plants by clipping with contaminated scissors (table 46). Sixty percent of the plants became diseased within 1 week after only parts of subterminal leaves were clipped (Treatment No. 1). All plants either were killed or showed severe wilt symptoms within 1 week after they were clipped with contaminated scissors either to remove terminal buds and two terminal leaves (Treatments No. 2 and No. 3) or to remove all terminal growth above three axillary buds (Treatments No. 4 and No. 5) (fig. 7). Treatment No. 1 is a form of control clipping, whereas Treatments No. 2, No. 3, No. 4, and No. 5 are forms of moderate clipping. These results showed that *P.*

TABLE 46.—*Tomato transplants showing symptoms of bacterial wilt 1 week after clipping diseased and healthy plants*

| Treatment No.	Treatment[1][2]	Transplants dead or showing severe symptoms
		Percent
1........	Subterminal leaves clipped (method A) alternately.	60
2........	Terminal bud and two terminal leaves clipped (method B) alternately.	100
3........	Same as No. 2 except plants were clipped successively.	100
4........	Plants clipped alternately to leave three axillary buds (method C).	100
5........	Same as No. 4 except plants were clipped successively.	100
6........	Control plants clipped alternately by methods A, B, and C.	0

[1] 10 plants were clipped in each treatment except for the controls (treatment No. 6) where 2 plants were clipped by method A, 5 by method B, and 5 by method C.

[2] With alternate clipping the scissors were used to cut a diseased plant each time before clipping a healthy plant. With successive clipping the scissors were cut into a diseased plant before clipping a series of healthy plants.

Source: *(40)*.

solanacearum could be spread in young tomato transplants by clipping and suggested that field spread of the bacterium among tomato transplants by clipping is likely.

The greenhouse findings were confirmed in field tests conducted in 1968 *(41)*. Beds of tomato transplants were established according to recommended practices. When the plants were 8 inches tall, a modified rotary lawn mower (fig. 8) was used to simulate clipping as practiced by the grower. The mower was contaminated with *P. solanacearum* before clipping by rubbing either a bacterial suspension grown in culture or a diseased plant onto the mower blade. A high percentage of tomato transplants were killed when the mower was contaminated with *P. solanacearum* before clipping (table 47 and fig. 9). Initial symptoms appeared as a dark-brown
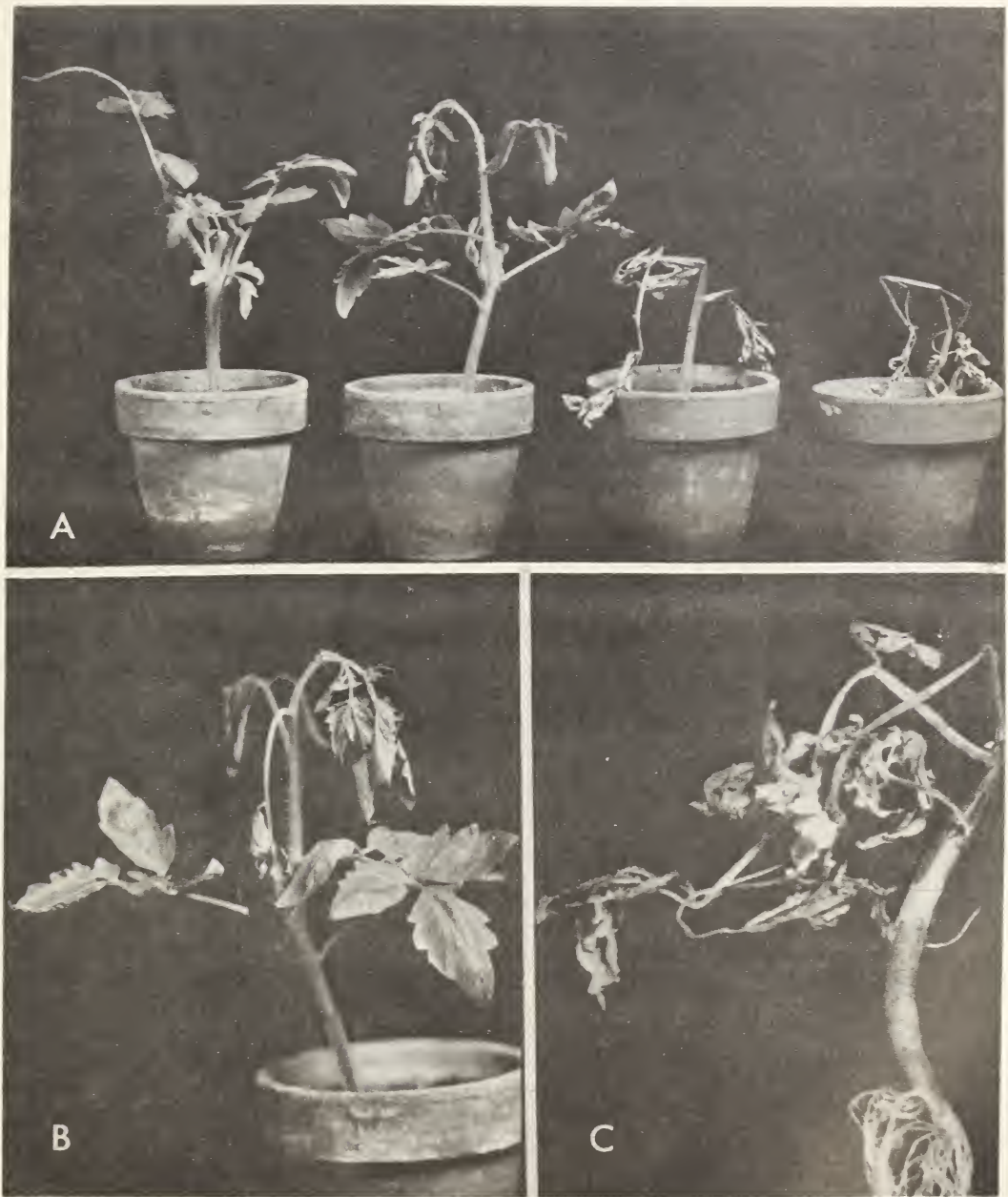
FIGURE 7.—Tomato transplants 5 days after clipping. *A, Left to right*—control transplant, leaves clipped, terminal bud and two terminal leaves clipped, and terminal growth above three axillary buds clipped; *B*, initial symptoms of bacterial wilt on plant with leaves clipped; *C*, severe symptoms of bacterial wilt on plant with terminal bud and two terminal leaves clipped. Note the dark-brown lesion that has extended down from the clipped end of the stem. Adapted from *(40)*.

PN-2722

FIGURE 8.—Clipping tomato transplants with a modified rotary lawn mower to study the spread of *Pseudomonas solanacearum* and tobacco mosaic virus. Adapted from *(41)*.

to black lesion on the cut end of the stem 5 to 6 days after clipping. This lesion progressed rapidly down the stem until the entire plant was killed. Wilt symptoms appeared shortly after the lesions became evident. Bacterial ooze was abundant on the clipped end of the stem, especially after rain.

Van Haltern *(61)* reported that in 1933 attempts to hand top transplants grown in Georgia for shipment failed because the wilt bacterium apparently was spread on the cutting blade, resulting in high mortality. Our findings corroborate these findings. However, the results do not necessarily indicate that clipping will result in serious losses of tomato transplants to bacterial wilt. Plants infected with *P. solanacearum* normally wilt so severely that the mower probably would contact a relatively low percentage of diseased plants unless the plants were clipped moderately. However, these results do indicate the potential danger involved in clipping plants in fields where this organism is present and suggest that certain precautionary measures should be taken.

TABLE 47.—*Tomato transplants killed after clipping with mower contaminated with* P. solanaccarum

Treatment [1]	Transplants killed in.[2][3]		
	Plot A	Plot B	Plot C
	Percent		
Bacterial suspension rubbed onto blade	92.8	93.2	82.5
Diseased plant rubbed onto blade	89.0	88.8	65.1
Control	28.3	23.8	28.6

[1] On May 24 an artificially contaminated mower was used to clip Plot A. On June 3 the mower, not artificially contaminated, was used to clip Plot B and then Plot B. On June 12 the mower, not artificially contaminated, was used to clip Plot B and then Plot C.

[2] Each value is average of 3 replicates for the bacterial treatments and 1 replicate for the control.

[3] Stand reductions in the control and probably equal damage in the other treatments were caused by *Sclerotium rolfsii*.

Source: *(41)*.

Southern Blight

Southern blight on many crops, including tomato transplants, has been controlled mainly by good cultural practices. In Georgia, Worley, Morton, and Harmon *(63)* found that deep plowing during land preparation reduced the incidence of southern blight in tomatoes grown for fruit production. In their tests, shallow tillage

FIGURE 9.—Beds of tomato transplants after moderate clipping *(left)* and after clipping with a rotary mower contaminated with *Pseudomonas solanacearum (right)*. Adapted from *(41)*.

was done with a harrow and deep (10 inches) turning was done with a moldboard plow equipped to bury surface trash in the bottom of the furrow (table 48). Although these tests were conducted on tomatoes grown for fruit production, the results should also apply to transplant production because burial of organic matter by deep plowing deprives the causal organism of a food base essential for disease development.

Calcium compounds, especially calcium nitrate, have been reported to reduce southern blight in tomatoes grown for fruit production in certain areas. However, Worley and Morton *(62)* found that calcium nitrate and several other calcium compounds failed to control southern

blight under severe disease conditions in Georgia (table 49). These workers also found *(49)* that the soil fungicides pentachloronitrobenzene (PCNB), 2,3,5,6-tetrachloro-4-nitroanisole (TCNA), and 1,4-dichloro-2,5-dimethoxy-benzene (DCDMB) failed to control southern blight on tomatoes grown for fruit production in Georgia. It is difficult to extrapolate these results to control of southern blight in transplant fields because transplants are produced early in the season, when blight is usually less severe. These findings do indicate, however, the difficulty of controlling this soilborne disease chemically under conditions that are optimum for disease development.

These results suggest that the most practical

TABLE 48.—*Tomato plants showing symptoms of southern blight at varying intervals after transplanting and after 2 tillage practices 1965*[1]

Days after transplanting	Plants in plot tilled with—				Cumulative total significant at 5 percent level
	Harrow (shallow-turned)		Plow (deep-turned)		
	Diseased	Cumulative total	Diseased	Cumulative total	
	.... Number				
28	2.7	2.7	0.8	0.8	No.
35	.8	3.5	.3	1.2	No.
42	1.0	4.5	.2	1.3	Yes.
49	.7	5.2	.3	1.7	Yes.
56	.3	5.5	.0	1.7	Yes.

[1] Average of 26 plants per plot.
Source: *(63)*.

TABLE 49.—*Plant survival following various calcium compounds applied for control of southern blight*

Compounds tested [1]	Average surviving plants per replication on [2] [3]—					Average
	May 25	June 6	June 18	June 27	July 6	
	. . . . *Number*					
Calcium nitrate, ... superphosphate, muriate of potash.	15.5	11.1	7.8	4.0	2.2	8.1
Gypsum, ... superphosphate, muriate of potash.	14.8	12.8	10.3	6.8	3.3	9.6
Ammonimum nitrate, . . superphosphate, muriate of potash.	15.2	11.0	7.5	4.2	2.8	8.1
Ammonium nitrate, ... superphosphate, muriate of potash, calcium chloride.	15.8	12.5	9.7	4.7	3.2	9.2
Ammonium nitrate, ... superphosphate, muriate of potash, limestone.	15.3	12.3	11.2	8.2	5.7	10.5
Average	15.3	11.9	9.3	5.6	3.4	. . . .

[1] Nitrogen, phosphorus, and potassium supplied at rates of 50, 44, and 83 pounds per acre, respectively, from the sources listed.

[2] Average for 6 replications, each originally including 17 plants set out April 17. All diseased plants showed signs of *Sclerotium rolfsii*.

[3] LSD 0.05 treatments 2.7; LSD 0.05 dates - 0.9.

Source: (62).

control for southern blight at the present time (1972) is the use of cultural practices such as deep plowing and crop rotation. However, future research may prove that broad-spectrum soil fumigants such as methyl bromide or selective fungicides may be effective and practical for control of southern blight as well as other soilborne diseases.

Bacterial Spot

To study the influence of temperature on the development of bacterial spot caused by *Xanthomonas vesicatoria*, Morton (48) studied disease development in excised tomato leaves at temperatures of 17.5°, 20.0°, 22.5°, 25.0°, 27.5°, and 30.3° C. The results are shown in table 50. Optimum temperature for rapidity (length of incubation period) and severity (maximum disease development) of disease development was from 25.0° to 27.5°.

Pythium Seedling Blight and Stem Rot

In recent years (1966 to 1972), a stem rot caused mainly by *Pythium aphanidermatum* and occasionally by *Pythium myriotylum* Drechs has caused considerable losses in certain tomato transplant fields. The disease was first recognized as a problem about 1966 and has occurred sporadically since that time. The main symptom is the presence of dark-brown to black lesions that begin near the soil level and may extend several inches up the stem. The root system frequently becomes necrotic.

Isolations made from diseased tomato transplants during 1966 and 1967 yielded *P. aphanidermatum*. Isolations made from diseased transplants in 1968 also yielded *P. myriotylum*. In that year we showed that *P. myriotylum* was pathogenic to tomato (42). When planted in soil infested with this organism, many tomato seed

TABLE 50.—*Rapidity and severity of bacterial spot development in excised tomato leaves incubated at different temperatures* [1]

Incubation temperature (°C.)	Length of incubation period [2]—		Maximum disease development [3]	
	Test 1	Test 2	Test 1	Test 2
Days				
17.5	7.6±2.6	7.0±0.0	1.9±0.3	1.1±0.3
20.0	7.1±0.1	6.9±0.4	2.1±0.5	2.0±0.4
22.5	6.2±0.3	6.4±0.3	2.6±0.7	2.5±0.3
25.0	6.0±0.4	6.1±0.3	3.1±0.3	3.0±0.6
27.5	6.1±0.5	6.0±0.5	3.2±0.4	2.8±0.3
30.0	7.7±1.3	7.3±1.1	1.1±0.5	1.3±0.4
Range 20 to 35 (in greenhouse).	5.9±0.6	5.5±0.6	3.3±0.3	3.2±0.3

[1] Each value is the mean of 10 replications. Data followed by ± standard deviation.

[2] Days until first definite symptoms appeared.

[3] Rated as follows: 1 = necrotic specks < 1 mm. in diameter; 2 = necrotic lesions 1-3 mm. in diameter; 3 = necrotic and chlorotic lesions 3-5 mm. in diameter; and 4 = necrotic and chlorotic lesions 5 mm. in diameter.

Source: *(48).*

failed to germinate but more commonly the young seedlings emerged only to decay near the soil surface. When established plants 3 inches tall were inoculated with *P. myriotylum*, severe stunting and stem lesions appeared. This stem rot of tomato was similar to that caused by the more widely occurring *P. aphanidermatum*.

Field observations indicated that pythium stem rot was favored by high temperature and high moisture although the disease was also observed to some degree during dry growing seasons. Low temperature appeared to be the main limiting factor to disease development, whereas a dense canopy resulting from high plant populations appeared to be conducive to disease development.

The potential threat of stem rot on tomato transplants caused by these *Pythium* species prompted us to study the influence of temperature on the causal organisms and on disease development and the susceptibility of various crops to the organisms.

Influence of Temperature on the Causal Organisms and on Disease Development

Laboratory and greenhouse tests were made to study the influence of temperature on growth of *P. aphanidermatum* and *P. myriotylum* in culture and on disease development. These causal organisms were grown on V-8 juice agar at 12 temperatures ranging from 11° to 43° C. (4° increments from 11° to 31°, and 2° increments above 31°) to study the influence of incubation temperatures on their growth. Constant soil temperatures from 15° to 35° at 4° increments were maintained with water baths to study the influence of temperature on disease development.

Both *Pythium* species grew at incubation temperatures from 15° to 43° C. with an optimum at 35° (fig. 10). The *P. aphanidermatum* colonies attained a greater diameter at 43° than *P. myriotylum*, whereas the converse was true at 11°. Generally, *P. aphanidermatum* grew slightly faster than *P. myriotylum*.

In preemergence tests (fig. 11), when soil was infested with *P. aphanidermatum*, disease development on plants increased as soil temperatures increased up to 27° C., at and above which temperature all plants were killed. When soil was infested with *P. myriotylum*, disease development on plants increased as soil temperatures increased from 19° to 35°, at which temperature nearly all plants were killed. Stand counts were not reduced at 15° by *P. aphanidermatum*; however, stand counts were reduced approximately 20 percent by *P.*
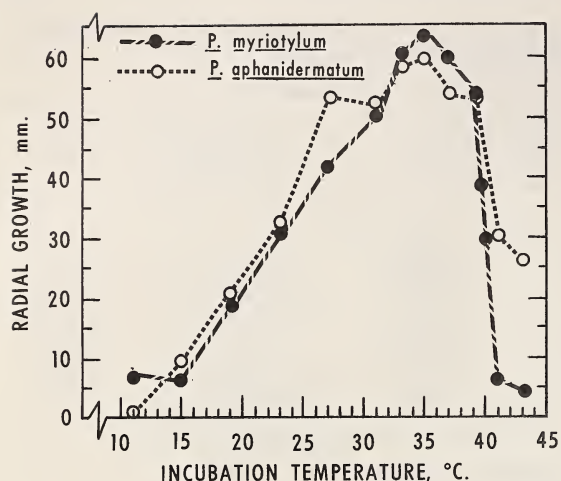
FIGURE 10.—The effect of incubation temperature on radial growth of *Pythium aphanidermatum* and *P. myriotylum* on V-8 juice agar. Adapted from *(35)*.

myriotylum at 15° and 19° . Optimum temperature for disease development on established tomato plants was 35° for both *Pythium* species (fig. 12).

These studies showed that both *Pythium* species require high temperatures for maximum growth and for disease production. These temperature data probably explain why stem rot is most severe late in the growing season.

Susceptibility of Various Crops to Pythium *spp.*

A knowledge of the susceptibility of various crops to a given organism is often important in planning a crop rotation to reduce disease losses. For this reason, we considered it important to test the susceptibility of some major Georgia crops to *P. aphanidermatum* and *P. myriotylum*.

Greenhouse pathogenicity tests were made with 'Campbell 17' tomato, 'Tendercrop' bean, 'Boston Pickling' cucumber, 'Wrens Abruzzi' rye, 'Florida 500' oats, 'Georgia 1123' wheat, 'Hicks' tobacco, 'Early Runner' peanut, 'Lindsey 77F' sorghum, 'Hampton' soybean, 'Atlas 66' cotton, and 'Dixie 18' corn *(43)*. Preemergence and postemergence inoculations were made on all crops except tobacco, which was inoculated only after transplanting. Fourteen isolates of each *Pythium* species were used to determine variability in virulence among isolates.

The crops differed greatly in susceptibility to the two organisms when seed were planted in infested soil (fig. 13) and when established plants were inoculated (fig. 14). In general, tomato, bean, rye, and tobacco were the most susceptible and cotton and corn were the most resistant. The two *Pythium* species often differed in pathogenicity on a given plant species, and individual isolates of each organism varied in virulence on susceptible crops (fig. 15). Susceptibility of the various crops to the two organisms also varied with plant age.

These results should provide some guidelines for selecting crops for use in future rotation studies. Corn appears to be worth considering because it was highly resistant to both *Pythium* species. Sorghum was also highly resistant to all isolates of *P. aphanidermatum* but was moderately susceptible to several isolates of *P. myriotylum*. Obviously, many factors other than disease resistance must be considered when selecting crops to be used in rotation.

Tobacco Mosaic Virus

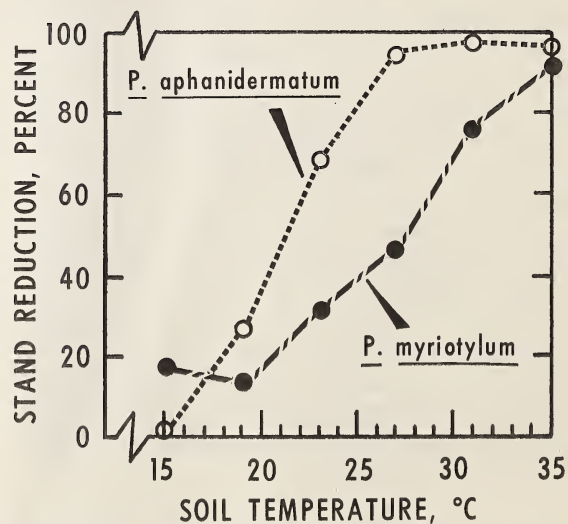Tobacco mosaic virus (TMV) does not cause significant losses of tomato transplants grown in

FIGURE 11.—The effect of soil temperature on damage to 'Campbell 17' tomato 14 days after seeding in soil infested with *Pythium aphanidermatum* and *P. myriotylum*. Adapted from *(35)*.
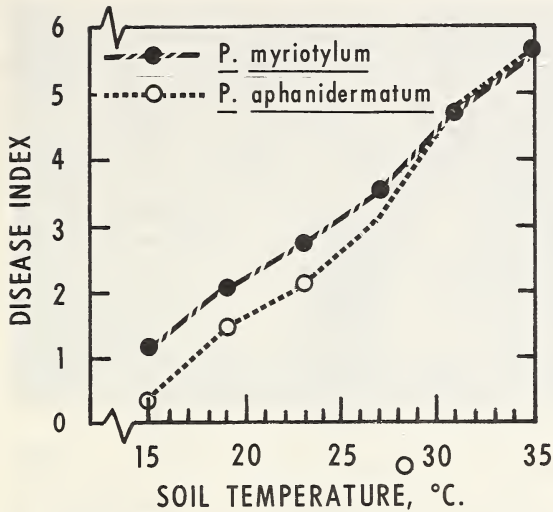
FIGURE 12.—The effect of soil temperature on damage to 'Campbell 17' tomato 14 days after postemergence inoculation with *Pythium aphanidermatum* and *P. myriotylum*. Adapted from *(35)*. Disease Index: 0-no disease; 1-5-increasing degrees of root and stem rot; and 6-plant dead.

Georgia. Although TMV occurs only rarely, we became interested in the disease because even an occasional infected plant could be potentially dangerous when plants are clipped.

In 1967 and 1968 we conducted field tests to determine the spread of TMV by clipping and to evaluate various mower-cleaning methods to eliminate virus contamination *(41)*. Transplant beds either 60 or 80 feet long and each with four rows were established according to recommended practices. Two weeks before the first clipping, one plant at the end of each row was inoculated with an isolate of TMV. Mosaic symptoms were usually evident within 2 weeks after inoculation. To study virus spread, we first clipped the infected plant at the end of each row and then clipped the plants the entire 60- or 80-foot length of the bed. Plants were clipped either three or four times at 7- to 10-day intervals in 1967 and two or three times in 1968. Control plants were clipped similarly except that none of the plants were inoculated. In 1968 some beds were inoculated with the virus but were not clipped; these beds served as a check against possible spread by means other than by mower

contact. In both years four replicates (beds) were used for each treatment.

In both the 1967 and the 1968 tests, clipping spread TMV from infected plants to healthy plants located considerable distance away (table 51). Disease on plants 50 to 60 feet from the inoculum source ranged from 62.9 to 90.1 percent in the treated beds. Mean disease incidence in the treated beds ranged from 69.7 to 88.9 percent. Mean disease incidence in control beds was 4.9 percent in 1967 and 13.2 in 1968.

Fortunately, TMV presently (1972) occurs very infrequently in tomato transplant fields, so it is not likely to become a serious problem as the result of clipping. However, our results demonstrate the danger involved in clipping transplants in a field where even a few plants are infected with this virus.

In the 1968 tests, various mower-cleaning methods were also evaluated to determine the most effective means of cleaning a mower accidentally contaminated with TMV. Before each test plot of disease-free transplants was clipped, the mower was contaminated by using it to clip TMV-infected plants. The mower then either was used directly to clip transplants (control) or was subjected to one of the following cleaning methods before use: (1) Washed with tapwater; (2) washed with tapwater followed by a 3-minute
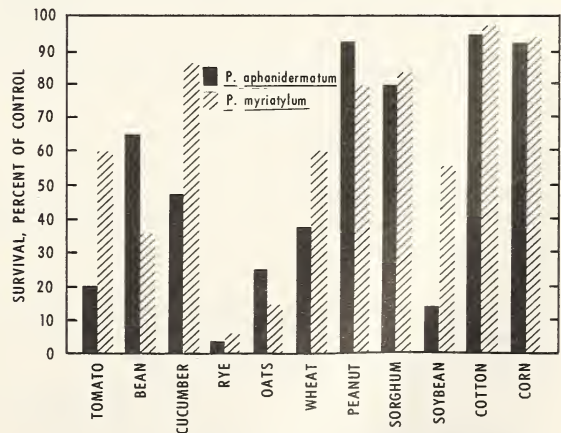

FIGURE 13.—Survival of 11 plant species 14 days after seeding in soil infested separately with *Pythium aphanidermatum* and *P. myriotylum*. Each bar represents the average of data resulting from inoculation with 14 isolates. Adapted from *(43)*.
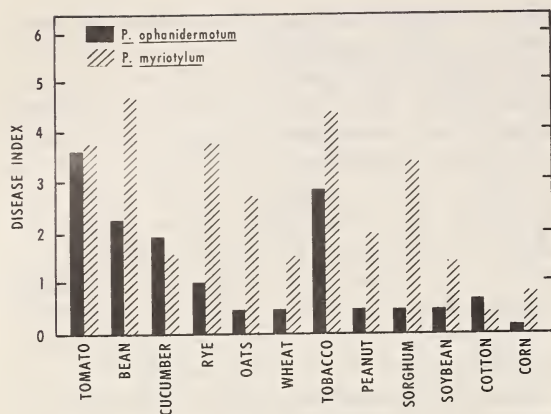
FIGURE 14.—Diseases indices on 12 plant species 14 days after post-emergences inoculation with *Pythium aphanidermatum* and *P. myriotylum*. Each bar represents the average of data resulting from inoculation with 14 isolates. Adapted from *(43)*. Disease Index: 0-no disease; 1-5-increasing degrees of root and stem rot; and 6-dead plant.

PN-2724

FIGURE 15.—Tomato plants 14 days after postemergence inoculation with 14 isolates of *Pythium aphanidermatum*: *A*, Control plant; *B*, plant inoculated with least virulent isolate; *C*, plant inoculated with most virulent isolate. Adapted from *(43)*.

TABLE 51.—*Tomato transplants infected with tobacco mosaic virus (TMV) after clipping.* *1967 and 1968*[1]

Year and treatment	TMV on plants at different distances from inoculum source								Mean
	0-10 feet	10-20 feet	20-30 feet	30-40 feet	40-50 feet	50-60 feet	60-70 feet	70-80 feet	
	. . . . *Percent*								
1967:									
Inoculated with virus-clipped 3 times.	93.7	79.8	71.6	52.7	62.6	66.9	71.2	67.3	70.7
Inoculated with virus-clipped 4 times.	97.5	91.4	88.9	90.1	82.8	90.1	80.1	87.1	88.9
Control: Not inoculated with virus-clipped 2 or 4 times.[2]	11.3	13.6	4.4	2.2	2.6	1.7	2.0	6.3	4.9
1968:[3]									
Inoculated with virus-clipped 2 times.	79.5	65.3	68.2	66.7	75.8	62.9	....	....	69.7
Inoculated with virus-clipped 3 times.	87.9	81.4	69.9	72.7	80.7	73.3	....	....	77.7
Control: Not inoculated with virus-clipped 3 times.	14.6	11.3	12.0	14.5	9.5	17.6	....	....	13.2
Inoculated with virus-not clipped.	3.4	0.0	0.4	0.2	0.2	0.0	....	....	0.7

[1] Each value is an average of 4 replicates.
[2] Two beds were clipped 3 times and 2 were clipped 4 times.
[3] Plot length was only 60 feet in 1968.
  Source: *(41)*.

soak in a strong detergent solution (1 pint of Tide in 1 gallon of water); (3) washed with tapwater followed by washing with skim milk (1 quart of Carnation Instant in 1 gallon of water); and (4) washed with tapwater followed by washing in a 10-percent Clorox solution. The cleaning solutions were not rinsed off after application.

The skim milk wash was the most effective cleaning method tested, as indicated by the lower percentage of infected transplants after clipping (table 52). The Clorox and detergent washes were similar to each other in effectiveness. Although the wash with water alone was the least effective cleaning method tested, it reduced subsequent infection of transplants by more than one-half that of the control (mower not washed). None of the methods were particularly effective when transplants were clipped two times, which probably indicates that the few transplants infected as the result of the first clipping served as inoculum sources during the second clipping.

TABLE 52.—*Tomato transplants infected with tobacco mosaic virus (TMV) after clipping with contaminated mower and after clipping with mowers subjected to various cleaning methods, 1968*[1]

Contaminated mower washing materials	TMV on plants at different distances from inoculum source						
	0-10 feet	10-20 feet	20-30 feet	30-40 feet	40-50 feet	50-60 feet	Mean
	.... Percent						
Not washed (control) [2]	48.6	61.0	20.3	15.8	19.2	23.7	31.1
Tapwater wash [3]	25.8 / 58.3	26.2 / 53.0	11.0 / 48.4	9.5 / 53.8	9.7 / 52.5	10.1 / 44.2	15.4 / 51.7
Tapwater wash plus .... soak in detergent. [3]	7.6 / 48.3	4.7 / 40.3	1.0 / 30.7	1.9 / 31.3	4.1 / 38.1	2.2 / 36.6	3.6 / 36.7
Tapwater wash plus .... skim milk wash. [3]	1.8 / 40.2	0.7 / 48.8	2.3 / 40.3	1.6 / 42.9	0.7 / 39.7	1.6 / 40.6	1.5 / 42.1
Tap water wash plus .... Clorox wash. [3]	6.8 / 59.0	2.0 / 51.6	1.6 / 42.1	4.7 / 53.1	10.7 / 48.3	6.0 / 64.6	5.3 / 53.1

[1] Each value in the control is an average of 4 replications; values for other methods are averages of 2 times replicates.

[2] Clipped 1 time.

[3] Clipped 1 time / clipped 2 times.

Source: *(41)*.

LITERATURE CITED

(1) ANONYMOUS.
1966. REGULATIONS FOR THE PRODUCTION OF GEORGIA CERTIFIED TOMATO PLANTS. Ga. Dept. Agr., Div. Ent. and Plant Indus., Atlanta. 6 pp.

(2) ———
1968. TOMATO PLANT CERTIFICATION FOR 1968. Ga. Dept. Agr., Div. Ent. and Plant Indus., Ga. Coastal Plain Sta., Tifton. 1 p.

(3) BARBER, J. M.
1967. GROWING TOMATO TRANSPLANTS. Ga. Coop. Ext. Release, Horticulture, 4, 5 pp.

(4) BORDERS, H. I.
1953. TRANSPLANTS GROWN IN THE SOUTH. U.S. Dept. Agr. Yearbook 1953: 463-465.

(5) ———HARDENBURG, R. E., and DOOLITTLE, S. P.
1955. PLASTIC BAGS AND CRATE LINERS FOR SHIPPING SOUTHERN-GROWN TOMATO TRANSPLANTS. Market Growers J. 84: 14, 31-32.

(6) BRODIE, B. B.
1970. USE OF NONSELECTIVE AND MIXTURES OF SELECTIVE PESTICIDES FOR MULTIPLE PEST CONTROL. Phytopathology 60: 12-15.

(7) ———GOOD, J. M., and JAWORSKI, C. A.
1970. POPULATION DYNAMICS OF PLANT NEMATODES IN CULTIVATED SOIL: EFFECT OF SUMMER COVER CROPS IN OLD AGRICULTURAL LAND. J. Nematol. 2: 146-151.

(8) BRODIE. B. B., GOOD, J. M., and JAWORSKI, C.A.
   1970. POPULATION DYNAMICS OF PLANT NEMATODES IN
         CULTIVATED SOIL: EFFECT OF SUMMER COVER CROPS
         IN NEWLY CLEARED LAND.   J. Nematol. 2: 217-
         222.
(9) _____ GOOD, J. M., JAWORSKI, C. A., and GLAZE,
   N. C.
   1968. MIXTURES OF SPECIFIC PESTICIDES AS OPPOSED TO
         BROAD SPECTRUM SOIL FUMIGANTS FOR MULTIPLE
         PEST CONTROL. U.S. Dept. Agr. Plant Disease
         Rptr. 52: 193-197.
(10) CAMPBELL SOUP COMPANY.
   1966. TOMATO TRANSPLANTS: REVIEW OF DEVELOPMENTS
         IN TOMATO PLANT FARMING, PLANT SIZE CONTROL,
         MECHANICAL HARVESTING, AND BARE ROOT SHIP-
         MENT.   Harvest (special agricultural issue)
         1: 2-5.
(11) _____
   1966. INSURANCE ACRES PAY OFF. Harvest 5:6-7.
(12) DUKES, P. D., MORTON, D. J., and JENKINS, S. F.,
   JR.
   1965. BACTERIAL WILT OF TAGETES MINUTA. U.S. Dept.
         Agr. Plant Disease Rptr. 49: 847-848.
(13) DUNCAN, D. B.
   1955. MULTIPLE RANGE AND MULTIPLE F TESTS. Biomet-
         rics 11: 1-42.
(14) FUTRAL, J. G., REID, J. T., and BUTLER, J. L.
   1957. PRECISION METERING DEVICE FOR FERTILIZERS AND
         OTHER MATERIALS USED IN FIELD PLOT WORK. Ga.
         Agr. Expt. Sta. Mimeo. Ser. (n. s.) 34, 6 pp.
(15) GLAZE, N.C.
   1968. PROGRESS REPORT ON HERBICIDES FOR DIRECT
         SEEDED TOMATOES. South, Weed Conf. Proc. 21:
         201.
(16) GOOD, J. M.
   1964. EFFECT OF SOIL APPLICATION AND SEALING METHODS
         ON THE EFFICACY OF ROW APPLICATIONS OF SEVERAL
         SOIL NEMATOCIDES FOR CONTROLLING ROOT-KNOT
         NEMATODES, WEEDS, AND FUSARIUM WILT.   U.S.
         Dept. Agr. Plant Disease Rptr. 48: 199-203.
(17) _____
   1968. RELATION OF PLANT PARASITIC NEMATODES TO SOIL
         MANAGEMENT PRACTICES. In Smart, G. C., Jr.,
         and Perry, V. G., eds., Tropical Nematology.
         pp. 113-138. Univ. of Florida Press, Gainesville.
(18) _____ MINTON, N. A., and JAWORSKI, C. A.
   1965. RELATIVE SUSCEPTIBILITY OF SELECTED COVER
         CROPS AND COASTAL BERMUDAGRASS TO PLANT
         NEMATODES. Phytopathology 55: 1026-1030.
(19) _____ and RANKIN, H. W.
   1964. EVALUATION OF SOIL FUMIGANTS FOR CONTROL OF
         NEMATODES, WEEDS, AND SOIL FUNGI. U.S. Dept.
         Agr. Plant Disease Rptr. 48: 194-199.
(20) _____ and STEELE, A. E.
   1958. SOIL FUMIGATION FOR CONTROLLING ROOT-KNOT
         NEMATODES ON TOMATO FOR TRANSPLANT AND FOR
         FRESH FRUIT PRODUCTION. U.S. Dept. Agr. Plant
         Disease Rptr. 42: 1173-1177.

(21) JACKSON, C. R.; GOOD, J. M., and RANKIN. H. W.
   1964. ROW FUMIGATION FOR CONTROL OF SOIL-BORNE
         FUNGI, NEMATODES, AND WEEDS.   Ga. Agr. Expt.
         Sta. Mimeo. Ser. (n. s.) 189, 19 pp.
(22) JAWORSKI, C.A.
   1965. EFFECT OF DOLOMITIC LIMESTONE ON TOMATO
         TRANSPLANT GROWTH, QUALITY AND MINERAL
         COMPOSITIONS. Fla. State Hort. Soc. Proc.
         78: 155-162.
(23) _____
   1966. CLIPPING VERSUS NON-CLIPPING ON UNIFORMITY OF
         TOMATO TRANSPLANTS. Fla. State Hort. Soc.
         Proc. 79: 209-211.
(24) _____
   1966. YIELD AND GROWTH UNIFORMITY OF TOMATO
         TRANSPLANTS IN RELATION TO NUTRITION LEVELS.
         Amer. Soc. Hort. Sci. Proc. 89: 577-583.
(25) _____
   1967. CHANGES IN PRODUCTION PRACTICES NEEDED TO
         FACILITATE MECHANICAL HARVESTING OF TOMATO
         TRANSPLANTS. Ga. Agr. Res. 8(3): 3-5.
(26) _____ McCARTER, S. M., and WEBB, R. E.
   1967. TOMATO TRANSPLANT RESEARCH WORKSHOP HELD IN
         GEORGIA. HortScience 2(2): 48-49.
(27) _____ and MORTON, D. J.
   1967. TOMATO TRANSPLANT GROWTH, PRODUCTION AND
         UNIFORMITY, IN RELATION TO SOURCES AND LEVELS
         OF NITROGEN. Hort. Res. 7: 1-12.
(28) _____ and VALLI, V. J.
   1964. TOMATO SEED GERMINATION AND PLANT GROWTH IN
         RELATION TO SOIL TEMPERATURES AND PHOSPHORUS
         LEVELS. Fla. State Hort. Soc. Proc. 77: 177-183.
(29) _____ and WEBB, R. E.
   1966 SURVIVAL AND YIELD OF TOMATOES AS INFLUENCED
        BY NUTRITION, CLIPPING AND STORAGE OF TRANS-
        PLANTS. Fla. State Hort. Soc. Proc. 79: 216-221.
(30) _____ and WEBB, R. E.
   1967 PRELIMINARY TESTS ON THE PERFORMANCE OF
        CLIPPED TOMATO TRANSPLANTS. Amer. Soc. Hort.
        Sci. Proc. 91: 550-555.
(31) _____ and WEBB, R. E.
   1968. PERFORMANCE OF STORED TOMATO TRANSPLANTS.
         (Abstract) Assoc. South. Agr. Workers Proc.
         65: 185.
(32) _____ WEBB, R. E., GARRISON, S. A., and OTHERS.
   1970. PERFORMANCE OF GROWTH-RETARDANT-TREATED
         TOMATO TRANSPLANTS.   HortScience 5(4): 255-
         256.
(33) _____ WEBB, R. E., and MORTON, D. J.
   1967. EFFECTS OF STORAGE AND NUTRITION ON TOMATO
         TRANSPLANT QUALITY, SURVIVAL, AND FRUIT YIELD
         Hort. Res. 7: 90-96.
(34) _____ WEBB, R. E., WILCOX, G. E., and
   GARRISON, S. A.
   1969. PERFORMANCE OF TOMATO CULTIVARS AFTER
         VARIOUS TYPES OF TRANSPLANT CLIPPING.
         Soc. Hort. Sci. 94: 614-616.

(35) LITTRELL, R. H., and McCARTER, S. M.
1970. EFFECT OF SOIL TEMPERATURE ON VIRULENCE OF PYTHIUM APHANIDERMATUM AND PYTHIUM MYRIOTYLUM TO RYE AND TOMATO. Phytopathology 60: 704-707.

(36) LOCASCIO, S. J. and WARREN, G. F.
1959. GROWTH PATTERN OF THE ROOTS OF TOMATO SEEDLINGS. Amer. Soc. Hort. Sci. Proc. 74: 494-499.

(37) McBETH, C. W.
1945. TEST ON THE SUSCEPTIBILITY AND RESISTANCE OF SEVERAL SOUTHERN GRASSES TO THE ROOT-KNOT NEMATODE HETERODERA MARIONI. Helminthol. Soc. Wash. Proc. 12: 41-44.

(38)_____ and TAYLOR, A. L.
1944. IMMUNE AND RESISTANT COVER CROPS, VALUABLE IN ROOT KNOT INFESTED PEACH ORCHARDS. Amer. Soc. Hort. Sci. Proc. 45: 156-158.

(39) McCARTER, S. M., DUKES, P. D., and JAWORSKI, C. A.
1969. VERTICAL DISTRIBUTION OF PSEUDOMONAS SOLANACEARUM IN SEVERAL SOILS. Phytopathology 59: 1675-1677.

(40)_____ and JAWORSKI, C. A.
1968. GREENHOUSE STUDIES ON THE SPREAD OF PSEUDOMONAS SOLANACEARUM IN TOMATO PLANTS BY CLIPPING. U.S. Dept. Agr. Plant Disease Rptr. 52: 330-334.

(41)_____ and JAWORSKI, C. A.
1969. FIELD STUDIES ON THE SPREAD OF PSEUDOMONAS SOLANACEARUM AND TOBACCO MOSAIC VIRUS IN TOMATO PLANTS BY CLIPPING. U.S. Dept. Agr. Plant Disease Rptr. 53: 942-946.

(42)_____ and LITTRELL, R. H.
1968. PATHOGENICITY OF PYTHIUM MYRIOTYLUM TO SEVERAL GRASS AND VEGETABLE CROPS. U.S. Dept. Agr. Plant Disease Rptr. 52: 179-183.

(43)_____ and LITTRELL, R. H.
1970. COMPARATIVE PATHOGENICITY OF PYTHIUM APHANIDERMATUM AND PYTHIUM MYRIOTYLUM TO TWELVE PLANT SPECIES AND INTRASPECIFIC VARIATION IN VIRULENCE. Phytopathology 60: 264-268.

(44) McGLOHON, N. E., HARRIS, E. D., and RATCLIFFE, J.T.
1967. DISEASE AND INSECT CONTROL IN TOMATO TRANSPLANT PRODUCTION. Univ. of Georgia Cooperative Ext. Release. Plant Pathology 1, 4 pp.

(45)_____ SASSER, J. N., and SHERWOOD, R. T.
1961. INVESTIGATIONS OF PLANT PARASITIC NEMATODES ASSOCIATED WITH FORAGE CROPS IN NORTH CAROLINA. N.C. Agr. Expt. Sta. Bul. 148.

(46) MILLER, E. V., MOORE, W. D., SCHOMER, H. A., and VAUGHAN, E. K.
1949. HANDLING AND SHIPPING SOUTHERN-GROWN TOMATO PLANTS. U.S. Dept. Agr. Cir. 805, 26 pp.

(47) MORAN, C. H., HARDENBURG, R. E., PEEL, R. D., and MOORE, J. F.
1962. COMMERCIAL PACKAGING AND TRUCK TRANSPORTATION OF BARE ROOT TOMATO PLANTS IN PLYETHYLENE-LINED CRATES. Amer. Soc. Hort. Sci. Proc. 81: 458-466.

(48) MORTON, D. J.
1966. BACTERIAL SPOT DEVELOPMENT IN EXCISED PEPPER AND TOMATO LEAVES. Phytopathology 56: 1194-1195.

(49)_____ and WORLEY, R. E.
1964. EFFECTS OF CALCIUM NITRATE, LIMESTONE, SOIL FUNGICIDES AND BLACK PLASTIC MULCH ON TOMATO SOUTHERN BLIGHT. U.S. Dept. Agr. Plant Disease Rptr. 48: 957-959.

(50) MURPHY, W.S.
1964. INFLUENCE OF ROW AND BROADCAST P FERTILIZATION ON THE GROWTH AND NUTRIENT STATUS OF SOUTHERN-GROWN TOMATO TRANSPLANTS. Fla. State Hort. Soc. Proc. 77: 122-127.

(51)_____
1964. PHOSPHORUS AND POTASSIUM NUTRITION OF SOUTHERN TOMATO TRANSPLANTS. Amer. Soc. Hort. Sci. Proc. 85: 478-483.

(52)_____
1965. INFLUENCE OF VARIOUS NITROGEN FERTILIZERS ON GROWTH AND NUTRITION OF SOUTHERN-GROWN TRANSPLANTS. Fla. State Hort. Soc. Proc. 78: 191-197.

(53) RATCLIFFE, T. J., and MORTO' D. J.
1963. DISEASES AFFECTING PRODUCTION OF CERTIFIED TOMATO PLANTS IN GEORGIA DURING 1942-1963. U.S. Dept. Agr. Plant Disease Rptr. 47: 1065-1066.

(54) SAUER, M. R., and GILES, J. E.
1957. EFFECT OF SOME FIELD MANAGEMENT SYSTEMS ON ROOT KNOT OF TOMATO. Nematologica 2: 97-107.

(55) SIMS, W. L.
1966. CLIPPING TOMATOR PLANTS AIDS MATURITY AND UNIFORMITY CONTROL FOR MECHANICAL HARVESTING. Calif. Agr. 20(11): 4-5.

(56) TAYLORSON, R. B.
1964. HERBICIDES FOR SEEDED TOMATOES. South. Weed Conf. Proc. 17th Ann. Meeting, pp. 207-214.

(57)_____
1965. DELAYED PREEMERGENCE WEED CONTROL IN SEEDED TOMATOES AND PEPPERS. Weeds 13: 306-308.

(58)_____
1966. SOME EFFECTS OF HERBICIDES ON BIOCHEMICAL CONSTITUENTS OF TOMATO PLANTS. /Amer. Soc. Hort. Sci. Proc. 89: 539-543.

(59)_____ JAWORSKI, C.A., and MURPHY, W. S.
1966. HERBICIDES FOR ESTABLISHMENT OF CROTALARIA AS A COVER CROP IN TOMATO TRANSPLANT PRODUCTION. Ga. Agr. Res. 7(4): 6-8.

(60) VALLI, V. J., and JAWORSKI, C. A.
    1965. INFLUENCE OF BIOMETEOROLOGICAL FACTORS IN TOMATO TRANSPLANT PRODUCTION. Fla. State Hort. Soc. Proc. 78: 102-106.
(61) VAN HALTERN, F.
    1935. CONTROL OF TOMATO SEEDBED DISEASES OF SOUTHERN PLANTS. Ga. Agr. Expt. Sta. Bul. 187, 39 pp.

(62) WORLEY, R. E., and MORTON, D. J.
    1964. INEFFECTIVENESS OF CALCIUM NITRATE AND OTHER CALCIUM SOURCES IN REDUCING SOUTHERN BLIGHT INCIDENCE ON RUTGERS TOMATO UNDER EPIPHYTOTIC CONDITIONS. U.S. Dept. Agr. Plant Disease Rptr. 48: 63-65.
(63) ———— MORTON, D. J., and HARMON, S. A.
    1966. REDUCTION OF SOUTHERN BLIGHT ON TOMATO BY DEEP PLOWING. U.S. Dept. Agr. Plant Disease Rptr. 50: 443-444.

ADDITIONAL RECENT REFERENCES

BRODIE, B. B.
    1971. DIFFERENTIAL VERTICAL MOVEMENT OF NON-VOLATILE NEMATICIDES IN SOILS. J. Nematol. 3: 292-295.
GLAZE, N. C.
    1971. EVALUATION OF SEVERAL HERBICIDES IN PLANTINGS OF DIRECT-SEEDED TOMATOES. South. Weed Conf. Proc. 24: 197.
GLAZE, N. C.
    1971. SOME HERBICIDAL EFFECTS ON THE BIOCHEMICAL COMPOSITION OF TOMATO PLANTS. (Abstract) Weed Sci. Soc. Amer., p. 90.
GLAZE, N. C.
    1971. EVALUATION OF SEVERAL HERBICIDES IN DIRECT-SEEDED TOMATOES. Weed Res. 11: 307-309.
GLAZE, N. C. and GAINES, T. P.
    1972. EFFECT OF HERBICIDES ON THE NITROGEN AND CARBOHYDRATE CONTENT OF DIRECT-SEEDED TOMATOES. Weed Sci. 20. (In press.)
HULBURT, W. C., and JAWORSKI, C. A.
    1971. A FERTILIZER-PLANTER FOR FIELD RESEARCH PLOTS TO PRODUCE VEGETABLE TRANSPLANTS. (Abbreviated abstract) J. Amer. Soc. Agr. Engin. 52: 541.

JAWORSKI, C.A., and WEBB, R. E.
    1971. PEPPER PERFORMANCE AFTER TRANSPLANT CLIPPING. HortScience 6(5): 480-482.
McCARTER, S. M., BARKSDALE, T. H., and JAWORSKI, C. A.
    1971. REDUCTION OF BACTERIAL WILT BY EARLY HARVEST OF TOMATO TRANSPLANTS. Phytopathology 61: 849-851.
RISSE, L. H.
    1970. PACKING AND SHIPPING BARE-ROOTED TOMATO TRANSPLANTS. U.S. Dept. Agr. Release, (dated January 14, 1970) 8 pp.
WELLS, H. D., BELL, D. K., and JAWORSKI, C.A.
    1972. EFFICACY OF TRICHODERMA HARZIANUM AS A BIOCONTROL OF SCLEROTIUM ROLFSII. Phytopathology 62: 442-447.
RISSE, L. A.
    1971. COMPARATIVE COSTS, RATES OF FIELD SURVIVAL, AND YIELDS OF BARE-ROOTED AND STANDARD-PACKED TOMATO TRANSPLANTS. U.S. Dept. Agr., Agr. Res. Serv. ARS 52-62, 18 pp.